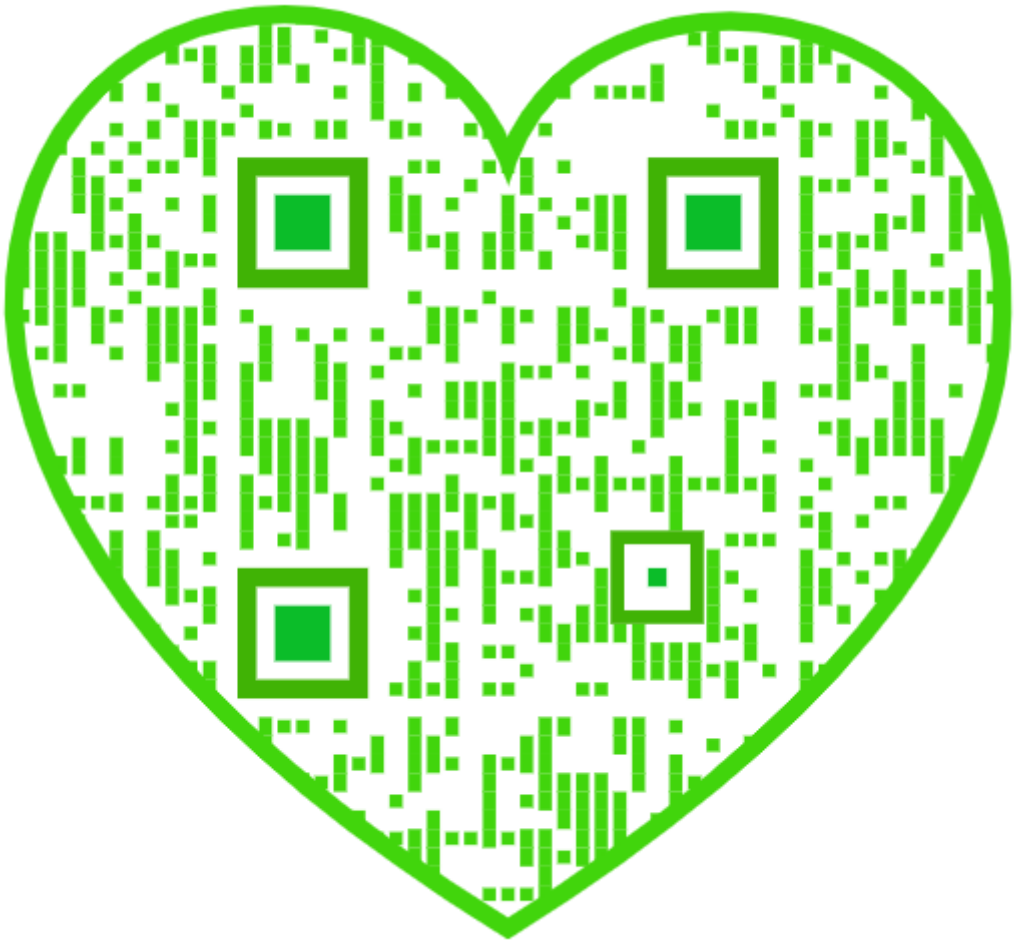

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EDITED BY

ISAAC BAYLEY BALFOUR, M.A., M.D., F.R.S.
PROFESSOR OF BOTANY IN THE UNIVERSITY
AND KEEPER OF THE ROYAL BOTANIC GARDEN, EDINBURGH

SYDNEY HOWARD VINES, M.A., D.Sc., F.R.S.
FELLOW OF MAGDALEN COLLEGE, AND SHERARDIAN PROFESSOR OF BOTANY
IN THE UNIVERSITY OF OXFORD

AND

WILLIAM GILSON FARLOW, M.D.
PROFESSOR OF CRYPTOGAMIC BOTANY IN HARVARD UNIVERSITY, CAMBRIDGE, MASS., U.S.A.

ASSISTED BY OTHER BOTANISTS

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CONTENTS.

No. XIII.

PAGE

MASSEE, GEORGE.—A monograph of the British Gastromycetes. (With Plates I, II, III, IV) 1

BARBER, C. A.—On a Change of Flowers to Tubers in Nymphaea Lotus, var. monstrosa. (With Plate V) 105

BATESON, ANNA.—On the Change of Shape exhibited by Turgescent Pith in Water 117

WAGER, HAROLD W. T.—Observations on the structure of the nuclei in Peronospora parasitica during the formation of the oospore. (With Plate VI) 127

SCOTT, D H.—On some recent progress in our knowledge of the Anatomy of Plants 147

NOTES.

GARDINER, WALTER.—A new application of Photography to the demonstration of certain physiological processes in plants . 163

MASTERS, MAXWELL T.—Double-flowered Ceanothus . . . 164

BOWER, F. O.—On Dr. Macfarlane's Observations on Pitchered Insectivorous Plants. (With Woodcuts 1, 2, 3) 165

BOWER, F. O.—Attempts to induce Aposporous Developments in Ferns 168

KEAN, A. L.—A Lily-disease in Bermuda 169

KEAN, A. L.—The Onion-disease in Bermuda 170

BENNETT, ALFRED W.—A Hybrid Desmid. (With Woodcut 4) . 171

BENNETT, ALFRED W.—Vaucheria-galls. (With Woodcut 5) . . 172

FARMER, J. BRETLAND.—The Stomata in the Fruit of Iris pseudacorus, Linn. (With Woodcuts 6, 7, 8, 9, 10, 11, 12, 13) . 174

JOHNSON, T.—Mystropetalon Thomii, Harv. 176

No. XIV.

ATKINSON, GEORGE F.—Monograph of the Lemaneaceae of the United States. (With Plates VII, VIII, and IX) . . . 177

WILSON, JOHN.—The Mucilage- and other Glands of the Plumbagineae (With Plates X, XI, XII, and XIII) 231

SCOTT-ELLIOT, G. F.—Note on the Fertilisation of Musa, Strelitzia reginae, and Ravenala madagascariensis. (With Plate XIV). 259

SCOTT-ELLIOT, G. F.—Ornithophilous Flowers in South Africa. (With Plate XV) 265

LISTER, ARTHUR.—Notes on Chondrioderma difforme and other Mycetozoa. (With Plate XVI) 281

PAGE

NOTES.

HARTOG, MARCUS M.—On cortical fibro-vascular bundles in some species of Lecythideae and Barringtonieae 299

BENNETT, A. W.—Vaucheria-galls 300

No. XV.

OLIVER, F. W.—On Sarcodes sanguinea, Torr. (With Plates XVII, XVIII, XIX, XX, XXI) 303

RIDLEY, H. N.—On the method of fertilization in Bulbophyllum macranthum, and allied Orchids. (With Plate XXII A) . 327

HARTOG, MARCUS M.—A Monadine parasitic on Saprolegnieae. (With Plate XXII B) 337

BOWER, F. O.—On Antithetic as distinct from Homologous Alternation of Generations in Plants 347

NOTES.

VAIZEY, J. R.—Alternation of Generations in Green Plants . . 371

DRUCE, G. CLARIDGE.—Spergula pentandra, L. as an Irish Plant . 378

GREEN, J. R.—On the Changes in the Endosperm of Ricinus communis during germination 383

No. XVI.

RECORD OF CURRENT LITERATURE . . . . . i–cxviii

INDEX.

PAGE

A. ORIGINAL PAPERS AND NOTES.

ATKINSON, GEORGE F.—Monograph of the Lemaneaceae of the United States. (With Plates VII, VIII, and IX) 177

BARBER, C. A.—On a Change of Flowers to Tubers in Nymphaea Lotus, var. monstrosa. (With Plate V) 105

BATESON, ANNA.—On the Change of Shape Exhibited by Turgescent Pith in Water 117

BENNETT, ALFRED W.
A Hybrid Desmid. (With Wooodcut 4) 171
Vaucheria-galls. (With Woodcut 5) 172
Vaucheria-galls 300

BOWER, F. O.
On Dr. Macfarlane's Observations on Pitchered Insectivorous Plants. (With Woodcuts 1, 2, 3) 165
Attempts to induce Aposporous Developments in Ferns . . 168
On Antithetic as distinct from Homologous Alternation of Generations in Plants 347

DRUCE, G. CLARIDGE.—Spergula pentandra, L. as an Irish Plant . 378

FARMER, J. BRETLAND.—The Stomata in the Fruit of Iris pseudacorus, Linn. (With Woodcuts 6, 7, 8, 9, 10, 11, 12, 13) . . . 174

GARDINER, WALTER.—A new application of Photography to the demonstration of certain physiological processes in plants . 163

GREEN, J. R.—On the Changes in the Endosperm of Ricinus communis during Germination 383

HARTOG, MARCUS M.
On cortical fibro-vascular bundles in some species of Lecythideae and Barringtonieae 299
A Monadine parasitic on Saprolegnieae. (With Plate XXII B) . 337

JOHNSON, T.—Mystropetalon Thomii, Harv. 176

KEAN, A. L.
A Lily-disease in Bermuda 169
The Onion-disease in Bermuda 170

LISTER, ARTHUR.—Notes on Chondrioderma difforme and other Mycetozoa. (With Plate XVI) 281

MASSEE, GEORGE.— A Monograph of the British Gastromycetes. (With Plates I, II, III, and IV) 1

MASTERS, MAXWELL T.—Double-flowered Ceanothus 164

OLIVER, F. W.—On Sarcodes sanguinea, Torr. (With Plates XVII, XVIII, XIX, XX, XXI) 303

RIDLEY, H. N.—On the method of fertilization in Bulbophyllum macranthum, and allied Orchids. (With Plate XXII A) . 327

PAGE

SCOTT, D. H.—On some recent progress in our knowledge of the Anatomy of Plants 147

SCOTT-ELLIOT, G. F.

Note on the Fertilisation of Musa, Strelitzia reginae, and Ravenala madagascariensis. (With Plate XIV) 259

Ornithophilous Flowers in South Africa. (With Plate XV) . 265

VAIZEY, J. R.—Alternation of Generations in Green Plants . . 371

WAGER, HAROLD, W. T.—Observations on the Structure of the Nuclei in Peronospora parasitica during the formation of the oospore. (With Plate VI) 127

WILSON, JOHN.—The Mucilage- and other Glands of the Plumbagineae. (With Plates X, XI, XII, and XIII) . . . 231

B. LIST OF ILLUSTRATIONS.

a. PLATES.

I, II, III, IV. On British Gastromycetes (MASSEE).

V. On Nymphaea Lotus var. monstrosa (BARBER).

VI. On Nuclei in Peronospora parasitica (WAGER).

VII, VIII, IX. Lemaneaceae of the United States (ATKINSON).

X, XI, XII, XIII. On the Glands of Plumbagineae (WILSON).

XIV. On Fertilisation in Musa, Strelitzia, and Ravenala (SCOTT-ELLIOT).

XV. On Ornithophilous Flowers (SCOTT-ELLIOT).

XVI. On Chondrioderma difforme (LISTER).

XVII, XVIII, XIX, XX, XXI. On Sarcodes Sanguinea, Torr. (OLIVER).

XXII A. On Fertilization in Bulbophyllum (RIDLEY).

XXII B. On a parasitic Monadine (HARTOG).

b. WOODCUTS.

1–3. Observations on Pitchered Insectivorous Plants (BOWER). . . 166

4. Hybrid Desmid (BENNETT) 171

5. Vaucheria-galls (BENNETT) 173

6–13. Stomata in Fruit of Iris pseudacorus (FARMER) 175

C. RECORD OF CURRENT LITERATURE.

1. Books and Pamphlets i

2. Periodical Literature xxiv

RECORD OF CURRENT LITERATURE.

I. BOOKS AND PAMPHLETS.

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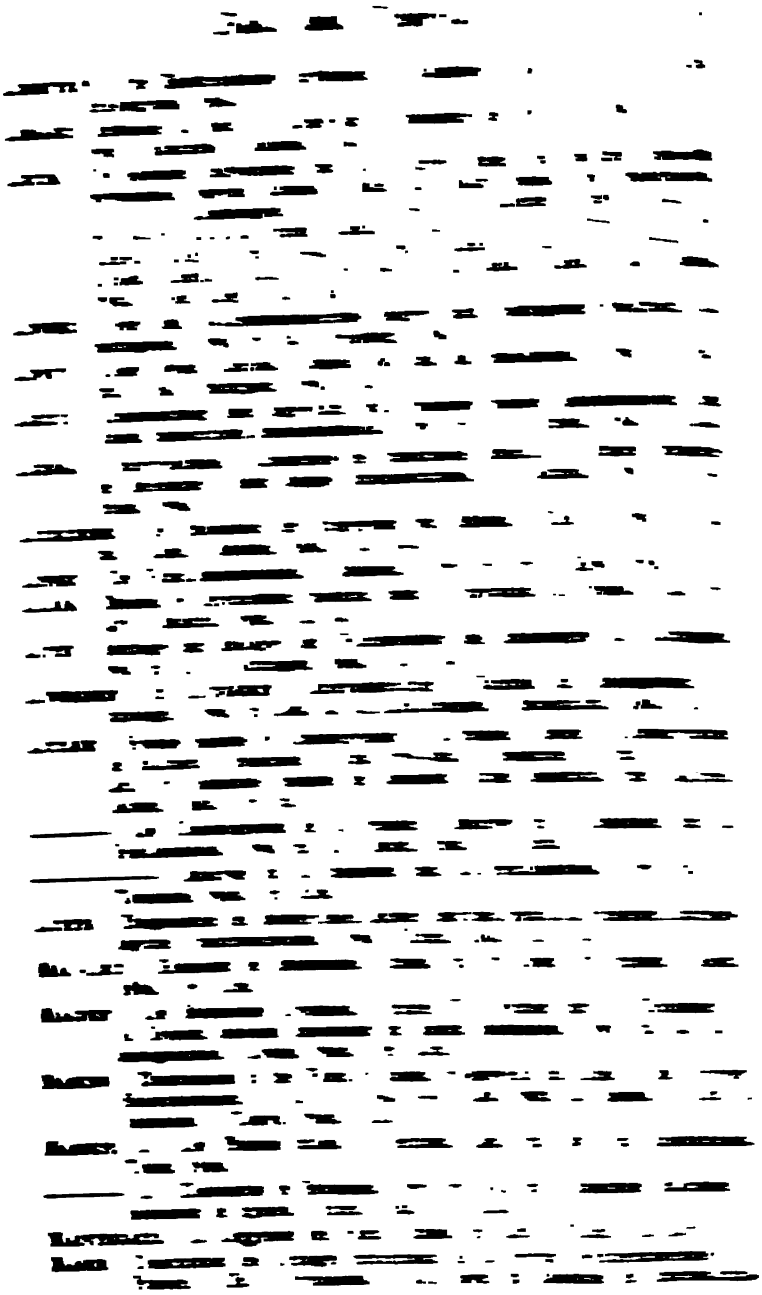

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CELAKOVSKÝ: Ueber eine neue mitteleuropäische *Daphne*.

Sitzungsberichte der königl. böhmischen Gesellschaft der Wissenschaften (*continued*).

HANSGIRG: Ueber neue Süsswasser- u. Meeres-Algen u. Bacterien, mit Bemerkungen zur Systematik dieser Phycophyten u. über den Einfluss des Lichtes auf die Ortsbewegungen der *Bacillus Pfefferi*, nob. (Taf. 1 u. 2.)

VANDAS: Neue Beiträge zur Kenntniss der Flora Bosniens u. der Hercegovina.

VELENOVSKY: Plantae novae bulgaricae. Pars II.

Természetrajzi Füzetek. (Buda-Pesth.) Papers not written in Latin published also in German, French, or English.

Vol. XII (*continued*).

No. 4. SIMONKAI: Novitates ex flora Hungarica.

„ — SCHILBERSZKY, JUN.: Beitrag zur Teratologie des Cotyledons der Schminkbohne. (Taf. VI.)

„ — RICHTER: Botanische Mittheilungen aus Ober-Ungarn. (Taf. VII, VIII.)

„ — BORBÁS: Die ungarischen Nelken als Gartenpflanzen.

Vol. XIII.

„ 1. SZÉPLIGETI: Beiträge zur Kenntniss der Verbreitung der Gallen mit besonderer Rücksicht auf die Umgebung von Budapest.

BORBÁS: *Quercus Budensiana* et species Botryobalanorum.

„ 2-3. ISTVANFFI: Algae nonnullae a Frivaldozky in Rumelia lectae.

BORBÁS: *Mentha Frivaldozkyana*, Borb. et species affines.

———: *Gypsophila digenea*, n. sp. hybr. et *G. arenaria*, W. et Kit. var. *leioclados*, n. var.

Természettudományi Közlöny. (Buda-Pesth.) 1890.

Füzet 245. HUTYRA: A baktérinuokról (illustrated, continued in Füz. 246).

„ 247. RÁTZ: A fertozo betegsegektol valo mentesseg kerdese.

BORBÁS: Az örökzöld és piteldó lomb.

„ 248. MAGOCSY-DIETZ: A növény biologia köréböl (illustrated).

„ 251. TELLYESNICZKY: A fény hatasa az allatokra (illustrated).

„ — ISTVANFFI: A hazigombarol.

„ 252. HANUSZ: A narasz *Acanthosicyos horrida*, Welw.

„ 254. TELLYESNICZKY: A fán lakó növény e kröl (illustrated).

Verhandlungen des Naturforschenden Vereines in Brünn. (Brünn, 1889.) Bd. XXVII.

Sitzungsberichte.

TOMASCHEK: Floristische Mittheilung, p. 29.

NIESSE: „ „ p. 32.

STEIGER: *Galinsoga parviflora* bei Auspitz, p. 34.

MAKOWSKY: Floristische Beiträge, p. 44.

Abhandlungen.

ZOEBL: Der anatomische Bau der Fruchtschale der Gerste, p. 205.

Verhandlungen der K. K. zoologisch-botanischen Gesellschaft in Wien (Vienna).

Bd. XXXIX (*continued*). Quartal IV.

BAUER: Ueber das Auftreten von *Volvox globator* in Wien.

BECK: Zur Pilzflora Niederösterreichs, V (Taf. XV).

Verhandlungen der K. K. zoologisch-botanischen Gesellschaft in Wien (*continued*).

DÖRFLER: Ueber Formen u. Monstrositäten des *Equisetum Telmateja*, Ehrh.

FRITSCH: Beiträge zur Flora von Salzburg, II.

———: Ueber einen neuen *Carduus*-Bastard.

STAPF: Ueber den Champignonschimmel als Vernichter von Champignonculturen.

———: Die neuen Ergebnisse der Stanley'schen Expedition.

THOMAS: Ueber das Vorkommen von *Exobasidium Warmingii*, Rostrup, in Tirol u. Piemont.

WEINZIERL: Ueber die Methoden der Werthbestimmung der Handelssamen.

WETTSTEIN: Untersuchungen über einige Orchideen.

ZUKAL: Ueber eine neue, niedrig organisirte Flechte.

Bd. XL. Quartal I.

BÄUMLER: Fungi Schemnitzenses, II.

BECK: Einige Bemerkungen zur systematischen Gliederung unserer Cruciferen.

BOEHM: Ursache der Wasserbewegung in transpirirenden Pflanzen. (With 3 woodcuts.)

COBELLI: Gli Apidi pronubi della *Brassica oleracea*, L.

FRITSCH: Ueber abnorm ausgebildete Inflorescenzen verschiedener Monocotylen.

HACKEL: Ueber einige Eigenthümlichkeiten der Gräser trockener Klimate.

KRASSER: Ueber die Aufgaben der wissenschaftlichen Paläophytologie.

PROCOPOVICI: Floristisches aus den Gebirgen der Bukowina.

RAIMANN: Ueber *Herpotrichia nigra*.

STUDNICZKA: Beiträge zur Flora von Süddalmatien.

Quartal II.

DÖRFLER: Ueber das Vorkommen von *Aspidium Luerssenii*, Dörfl., u. einiger anderer Farne in der Bukowina.

FRITSCH: Ueber die Gattung *Walleria*.

KRONFELD: Ueber das ätiologische Moment des Pflanzengeschlechtes.

PROCOPOVICI: Beitrag zur Kenntniss der Orchidaceen der Bukowina.

WETTSTEIN: Ueber Ergebnisse von Culturversuchen mit heteroecischen Uredineen.

———: Vorläufige Mittheilung von *Cytisus Laburnum*, L.

WIESNER: Ueber den absteigenden Transpirationsstrom.

ZAHLBRUCKNER: Beiträge zur Flechtenflora Niederösterreichs, III.

Quartal III.

BRAUN: Ueber einige Arten u. Formen der Gattung *Mentha* mit besonderer Berücksichtigung der in Osterreich-Ungarn wachsenden Formen. (Taf. VII and VIII.)

FRITSCH: Ueber die Auffindung der *Primula longiflora*, All., in Niederösterreich.

———: Ueber Calycanthemie bei *Soldanella*. (With woodcut.)

KERNSTOCK: Lichenologische Beiträge.

LENECEK: Ueber eine merkwürdige Verwachsung eines Baumastes mit dem Stamme desselben Baumes. (Illustrated.)

OSTERMEYER: Beitrag zur Flora von Kreta.

Zeitschrift, Oesterreichische botanische. (Vienna.) Jahrg. XL.

No. 1. KERNER: Die Bedeutung der Dichogamie.
„ — FREYN: Plantae Karoanae (*continued*) (continued in Nos. 2–4, 6–8).
„ — DEGEN: Zwei neue *Asperula*-Arten.
„ — BÄUMLER: Mycologische Notizen.
„ 2. HALÁCSY: Beiträge zur Flora der Balkanhalbinsel (continued in Nos. 3, 4, and 11).
„ — SZYSZYLOWICZ: Zwei neue Weinmannien aus Südamerika.
„ — HANSGIRG: Phytodynamische Untersuchungen.
„ — BAUER: Untersuchungen über gerbstofführende Pflanzen (continued in Nos. 3–5).
„ — FORMANEK: Zweiter Beitrag zur Flora von Bosnien u. der Hercegovina.
„ 3. WIESNER: Ueber das Saftperiderm.
„ — HACKEL: Eine zweite Art von *Streptochaeta*.
„ — BORBÁS: Kahl- u. behaartfrüchtige Parallelformen der Veilchen aus der Gruppe *Hypocarpeae* (continued in No. 4).
„ 4. WILLKOMM: Ueber neue u. kritische Pflanzen der spanisch-portugiesischen u. balearischen Flora (continued in Nos. 5 and 6).
„ — BREIDLER: Beitrag zur Moosflora der Bukowina u. Siebenbürgens (continued in No. 5).
„ — RECHINGER: *Ballota Wettsteinii*, n. sp. (Taf. I).
„ — BRAUN UND SENNHOLZ: *Calamintha mixta*.
„ — STEIN: *Petasites Kablikianus*.
„ — WETTSTEIN: Ueber das Vorkommen von *Trochobryum Carniolicum* in Südserbien.
„ 5. LAGERHEIM: *Puccinia* (*Micropuccinia*) *Bäumleri*, n. sp.
„ — DÖRFLER: Beiträge u. Berichtigungen zur Gefässkryptogamenflora der Bukowina (continued in Nos. 6 and 7).
„ 6. BAUER: Beitrag zur Phanerogamenflora der Bukowina u. des angrenzenden Theiles von Siebenbürgen (continued in Nos. 7 and 8).
„ — WETTSTEIN: Eine neue *Sambucus*-Art aus dem Himalaya. (Taf. II.)
„ 7. CELAKOVSKÝ: Ueber *Petasites Kablikianus*, Tausch. (continued in No. 8).
„ — ASCHERSON: *Carex refracta*, Willd. (1805) = *C. tenax*, Reuter (1856).
„ — DAMMER: Die extrafloralen Nectarien an *Sambucus nigra*.
„ — DALLA-TORRE: *Juniperus Sabina*, L. in den nördlichen Kalkalpen Tirols.
„ 8. ANGERER: Beitrag zur Laubmoosflora von Oberösterreich.
„ 9. ZUKAL: *Epigloea bactrospora*.
„ — HEINRICHER: Neue Beiträge zur Pflanzen-Teratologie u. Blüthen-Morphologie.
„ — SIMONKAI: Bemerkungen zur Flora von Ungarn.
„ — WETTSTEIN: Die Botanik auf der internationalen forst- u. landwirthschaftlichen Ausstellung in Wien.
„ 10. KERNER: Die Bildung v. Ablegern bei *Sempervivum* u. *Sedum dasyphyllum*.
„ — WETTSTEIN: Das Vorkommen der *Picea Omorica* (Panc.), Willk. in Bosnien.
„ — ZAHN: *Carex flava*, *Oederi*, u. *Hornschuchiana* u. deren Bastarde.
„ — BAENITZ: *Cerastium Blyttii*, Baen.
„ 11. WETTSTEIN: Untersuchungen über die Section 'Laburnum' der Gattung *Cytisus* (continued in No. 12.) (m. Taf.)

Zeitschrift, Oesterreichische botanische (*continued*).

No. 11. FREYN: Plantae novae Orientales (continued in No. 12).

„ — TAUBERT: Die Gattung *Phyllostylon*, Capan., u. ihre Beziehungen zu *Samaroceltis*, Poiss.

„ — DÜRRNBERGER: *Cirsium Stoderianum.*

„ — ZAHN: *Carex Kneuckeriana.*

„ — HALÁCSY: Neue Brombeerformen aus Oesterreich.

„ — MAGNUS: Ein neues Unkraut auf den Weinbergen bei Meran.

„ — KRONFELD: Die sogenannte Maria-Theresia-Palme.

BELGIUM.

Bulletin de l'Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique. 3e Sér. (Brussels, 1889–90.)

Tome XVIII.

MACLEOD, STAES, AND EECKHAUTE: Expériences de culture concernant *Mathiola annua* et *Delphinium Ajacis*. p. 715.

VANDENBERGHE: Étude des graines et de la germination des Salicornes de Heyst et de Terneuzen. p. 719.

Tome XIX.

LAURENT: Expériences sur l'absence de bactéries dans les vaisseaux des plantes. p. 468.

———: Expériences sur la production de nodosités chez le Pois à la suite d'inoculations. p. 764.

Tome XX.

LAURENT: Réduction des nitrates par la levure de bière et par quelques moisissures. p. 309.

COGNIAUX: Le nouveau genre *Posadaea* de la famille des Cucurbitacées.

LAURENT: La réduction des nitrates en nitrites par les graines et les tubercules.

Bulletin de la Société Belge de Microscopie. (Brussels, 1889–90.) Année XV (*continued*).

No. 10. WEVRE: La Lignine.

„ — DINEUR: Nouvelle méthode simplifiée et rapide pour la recherche du bacille de Koch dans les expectorations tuberculeuses.

Année XVI.

Nos. 1–3. LAURENT: Observations sur le champignon du muguet (illust.).

No. 4. WILDEMAN: Notes sur les genres *Prasiola*, Lightf., et *Schizogonium*, Kütz.

„ 5. DELOGNE: Genre *Coprinus*, Pers., analyse des espèces de Belgique et des pays voisins.

„ 8. LECLERCQ: Les Microorganismes intermédiaires aux deux règnes.

Nos. 9, 10. WILDEMAN: Note sur quelques Saprolegniées parasites des algues.

Bulletin de la Société Royale Linnéenne de Bruxelles. (Brussels, 1889–90.) Tome XV (*continued*).

Livr. 11. JANSSENS: Culture des Chrysanthemums.

Cellule, La. (Louvain, 1890.) Tome VI.

Fasc. 1. VENDRICKX: Contributions à l'action pathogène du Bacille commun de l'intestin.

„ — GILSON: La Subérine et les cellules du liège. (Plate.)

L'Illustration horticole. (Brussels, 1890.) Tome XXXVII.

La floraison nuit-elle aux Orchidées?

E. R.: La senteur de quelques fleurs d'Orchidées.

—— : Les Kakis du Japon.

GOEMANS: Les Gymnogrammes et leur culture.

——— : Culture des *Alocasia.*

——— : *Trichinium Manglesii.*

Also coloured plates, with text, of *Dianthus caryophyllus*, L., var.; *Croton variegatum* x Mull.; *Odontoglossum luteo-purpureum*, Lindl., var. *sceptrum*, subvar. *Masereelianum*; *Anthurium Scherzerianum*, var. *maximum album*; *Anguloa uniflora*, R. & P.; *Clivia miniata*, Lindl., var.; *Malpighia ilicifolia*, Mill.; *Azalea indica*, vars.; *Anthurium Andreanum*, J. Lind., var.; *Anthurium Scherzerianum*, Schott, var. *bispathaceum*, Rod.; *Alocasia* x *Bachi*, Hort.; *Haemanthus Lindeni*, N. E. Br.; *Cordyline indivisa*, Kth., var. *Dalliereana*, Hort.; *Gladiolus hybridus*, Hort.; *Nepenthes O'Brieniana*, L. Lind. et Rod.; *Catasetum Bungerothi*, N. E. Br., var. *Randi.*

Lindenia (J. Linden). Gand (1889–90).

Vol. V (*continued*). Livr. 5–12 contains plates of — *Odontoglossum maxillare*, Lindl.; *Aerides Augustianum*, Rolfe; *Cattleya maxima*, var. *Malonana*; *Rodriguezia refracta*, Rchb. f.; *Odontoglossum hastilabium*, Lindl.; *Houlletia Brocklehurstiana*, Lindl.; *Dendrobium Mirbelianum*, Gaud.; *Zygopetalum intermedium*, Lodd.; *Calanthe* x *Veitchii*, *Odontoglossum Duvivierianum*, Rchb. f.; *Masdevallia ignea*, Rchb. f.; *Lycaste costata*, Lindl.; *Oncidium aurosum*, Rchb. f.; *Cymbidium Mastersi*, Griff.; *Cypripedium* x *nitens*, Rchb. f.; *Odontoglossum Boddaertianum*, Rchb. f.; *Dendrobium Wardianum*, Warn., var. *Lowi*, Burbidge; *Laelia anceps*, Lindl., var. *Hyeana*, L. Lind., *Phalaenopsis Schilleriana*, Rchb. f.; *Cypripedium* x *barbato-Veitchianum*, A. Blew.; *Cattleya Trianae*, var. *Madame R. Martin-Cahuzac*, Lind., *C. Tr.*, var. *pallida*, Lind., *C. Tr.*, var. *purpurata*, Lind., *C. Tr.*, var. *striata*, Lind.; *Odontoglossum odoratum*, Lindl., var. *striatum*, Rchb. f.; *Oncidium Sarcodes*, Lindl.; *Ada aurantiaca*, Lindl.; *Angraecum eburneum*, Thouars, var. *superbum*; *Zygopetalum Jorisianum*, Rolfe, n. sp.; *Angraecum citratum*, Thouars; *Bifrenaria Harrisoniae*, Rchb. f.; *Odontoglossum Schlesingerianum*, L. Lind.

Vol. VI. Livr. 1–6 contains plates of *Dendrobium Galliceanum*, Lind.; *Selenipedium* x *grande*, Rchb. f.; *Coelogyne ocellata*, Lindl., var. *maxima*, Rchb. f.; *Coryanthes Bungerothii*, Rolfe; *Selenipedium* x *Sedeni, candidulum*, Rchb. f.; *Oncidium Kramerianum*, Rchb. f.; *Dendrobium Devonianum*, Paxt.; *Maxillaria longisepala*, Rolfe; *Cypripedium praestans*, Rchb. f., var. *Kimballianum*; *Masdevallia Reichenbachiana*, Endres.; *Dendrobium Dalhousieanum*, Paxt.; *Calanthe veratrifolia*, R. Br.; *Cypripedium* x *Fraseri*, Hort.; *Phaius Humbloti*, Rchb. f.; *Cirrhopetalum Mastersianum*, Rolfe; *Stanhopea oculata*, Lindl.; *Masdevallia bella*, Rchb. f.; *Coelogyne peltastes*, Rchb. f.; *Catasetum Rodigasianum*, Rolfe; *Chysis aurea*, Lindl.; *Cypripedium superbiens*, Rchb. f.; *Cattleya Eldorada*, Lind., var.; *Phalaenopsis Esmeralda*, Rchb. f., var. *candida*, n. var.; *Dendrobium superbum*, Rchb. f., var. *anosinum*, Rchb. f.

Mémoires de la Société Royale des Sciences de Liège. (Brussels.) Tome XVI.

LAMBOTTE: La flore mycologique de la Belgique. 2e supplément comprenant les Sphaeropsideae—Melanconieae—Hyphomycetes

Revue des Questions Scientifiques. (Brussels, 1890.) Année XIV.

Livr. 2. MEESSEN: La levure de bière: morphologie, physiologie, pathologie (illustrated) (continued in Livr. 3).

DENMARK.

Oversigt over det K. Danske Videnskabernes Selskabo Forhandlinger (L'Académie Royale de Copenhague-Bulletin). (Copenhagen, 1889–90.)

1889.

No. 2. NATHORST: Sur la présence du genre *Dictyozamites*, Oldham, dans les couches jurassiques de Bornholm. (Plate V.)

1890.

No. 1. ROSTRUP: Nogle Undersogelser angaaende *Ustilago Carbo*. (Plate I.)

„ — POULSEN: *Thismia Glaziovii*, n. sp. Bidrag til de brasilianske Saprofyters Naturhistorie. Plates II–IV.)

Tidsskrift, Botanisk. (Copenhagen.) XVII, Bind, Haefte 4.

KIAERSKON: Myrtaceae ex India occidentali a dominis Eggers, Krug, Sintensis, Stahl aliisque collectae. (Cum Tab. 7–13 et zincograph. 14) (*continued*).

POULSEN: *Triuris major*, n. sp. Et Bidrag til Triuridaceernes Naturhistorie. (Tab. XIV.)

BØRGESEN: Nogle Ericinee-Haars Udviklings-historie (illustrated.)

BAY: Tillæg til 'Den danske botaniske Literatur fra de ældste Tider til 1880, sammens Tillett af Eug. Warming.' 1. Fra de aeldste Tider indtil 1800.

FRIDERICHSEN ET GELERT: *Rubus commixtus*, n. subsp.

Videnskabelige Meddelelser fra den naturhistoriske Forening i Kjobenhavn for Aaret 1889. (Copenhagen, 1890.)

RAUNKIAER: Symbolae ad floram Brasiliae centralis cognoscendam. Edit. Eug. Warming. Particula XXXI. (Tab. I et II.)

EGGERS: Supplement til St. Croix's og Jomfruoernes Flora.

WARMING: Symbolae ad floram Brasiliae centralis cognoscendam, Particulae XXXII–III.

————: En. Stenfrugt med Sejbast (*Caryocar brasiliense*, Caml.) (Tab. III.)

FRANCE.

Actes de la Société Linnéenne de Bordeaux. (Bordeaux, 1890.)

Série V, Tome IV, Livraison 1.

LALANNE: Recherches sur les caractères anatomiques des feuilles persistantes des Dicotylédones. (Pl. I–VII.) (Continued in Livr. 2.)

Annales de la Science Agronomique. (Paris.)

1889, Tome I.

Fasc. 1. GAROLA: Contribution à l'étude du blé.

„ — BARTET: Étude sur la place de production no. 2 installée dans la forêt domaniale de Haye.

Annales de la Science Agronomique (*continued*).

Fasc. 1. MULLER: Recherches sur les formes naturelles de l'humus et leur influence sur la végétation et le sol (continued in Fasc. 2 and 3).

„ 3. EKERMAYER: Influence de la forêt et de la consistance des peuplements sur le degré d'humidité du sol. (Translated from the Allgemeine Forst- u. Jagd-Zeitung, Jan. 1889.)

„ — LECLERC: Recherche et dosage de l'amidon.

1890, Tome I.

Fasc. 1. GAYON: Recherches sur les engrais de la vigne.

„ — PETERMANN: Contribution à la chimie et à la physiologie de la betterave à sucre.

„ — HELLRIEGEL ET WILFARTH: Recherches sur l'alimentation azotée des graminées et des légumineuses. (Traduit de l'allemand par M. E. Gourier.)

Annales de la Société Botanique de Lyon. (Lyons, 1889.) Année XVI.

LACHMANN: Contributions à l'histoire naturelle de la racine des Fougères.

MAGNIN: Note sur l'Histoire des plantes de l'Europe (Petit-Bauhin).

———: Recherches sur le polymorphisme floral, la sexualité et l'hermaphrodisme parasitaire du *Lychnis vespertina*.

SAINT-LAGER: Vicissitudes onomastiques de la Globulaire.

————: La priorité des noms de plantes.

Annales de la Société d'Agriculture, &c., de Lyon. (Lyons and Paris, 1890.) Série VI, Tome II, 1889.

RAULIN: Expériences de chimie agricole.

———: Études de chimie agricole.

Annales de la Société des Sciences Naturelles de la Charente-Inférieure. (La Rochelle, 1889.) No. 25.

Excursions botaniques à Angoulins; au Gros-Roe, au Douhet et à St Hilaire; à Pessines; à Cadeuil; à Chaillé-les-Marais.

LLOYD: Note sur *Ranunculus Drouetii*.

BRUNAUD: Liste des Ustilaginées et des Urédinées récoltées dans la Charente-Inférieure.

———: Liste des Myxomycètes récoltées dans la Charente-Inférieure.

Annales de la Société Linnéenne de Lyon. (Lyons and Paris, 1890.) Tome XXXVI.

BATAILLON: Étude préliminaire sur la Cinèse nucléolaire.

Annales de l'Institut Pasteur. (Paris.)

Tome III (1889) (*continued*).

No. 12. GAMALEIA: *Vibrio Metchnikovi*: localisation intestinale. (Plate I.)

Tome IV (1890).

No. 1. FERNBACH: Formation de Sucrase chez l'*Aspergillus niger*.

„ — ROUX: Bactéridie Charbonneuse asporogène.

„ 2. GESSARD: Nouvelle recherches sur le microbe pyocyanique.

„ — GAMALEIA: Sur l'exaltation de la virulence du Bacille morveux.

„ 4. WINOGRADSKY: Recherches sur les organismes de la nitrification (continued in No. 5).

„ 6. KAYSER: Études sur la fermentation du cidre.

„ — GABRITCHEVSKY: Sur les propriétés chimotactiques des leucocytes.

Annales de l'Institut Pasteur (*continued*).

No. 6. HAFKINE: Recherches sur l'adaptation au milieu chez les Infusoires et les Bactéries.

„ 7. GABRITCHEVSKY: Contribution a l'étude de la Parasitologie du sang. (Plate VIII.)

„ — VALLARD ET VINCENT: Sur une pseudo-pélade de nature microbienne. (Plate IX.)

„ 8. LAURENT: Étude sur la variabilité du bacille rouge de Kiel.

„ — KAYSER: Étude des malts de brasserie.

„ — MALM: Sur la virulence de la Bactéridie Charbonneuse.

„ 9. SELANDIER: Étude de la Svinpest.

„ 10. CASSEDEBAT: Le Bacille d'Eberth-Gaffky et les Bacilles pseudo-typhiques dans les eaux de rivière.

„ — FERNBACH: Sur l'invertine ou sucrase de la levure.

„ — POPOFF: Sur un bacille anaërobic de la fermentation panaire.

„ 11. BLAGOVESTCHENSKY: Sur l'antagonisme entre les bacilles du charbon et ceux du pus bleu.

„ — LAURENT: Expériences sur la réduction des nitrates par les végétaux.

„ 12. DANILEVSKY: Sur les microbes de l'infection malarique aiguë et chronique chez les oiseaux et chez l'homme.

„ — WINOGRADSKY: Recherches sur les organismes de la Nitrification, III.

Annales de Micrographie. (Paris, 1889–90.)

Tome II (*continued*).

No. 3. FREUDENREICH: De la teneur du lait en bactéries.

„ 5. THÉLOHAN: Contributions à l'étude des myxosporidies.

„ — HANSEN: Sur la production de variétés chez les saccharomyces.

„ — GIAXA: Le bacille du choléra dans le sol.

„ 6. FREUDENREICH: Recherches préliminaires sur le rôle des bactéries dans la maturation du fromage de l'Emmenthal.

„ 7. BOVET: Des gaz produits par la fermentation anaërobienne.

„ — VINCENT: Sur un nouveau procédé d'isolement du bacille typhique dans l'eau. (*v.* also No. 9.)

„ 8. FREUDENREICH: Sur quelques bactéries produisant le boursouflement des fromages.

„ — DOWDESWELL: Note sur les flagella du microbe du choléra.

„ — LINOISSIER ET ROUX: Sur la morphologie et la biologie du champignon du muguet.

„ 10 et 11: GASPERINI: Recherches morphologiques et biologiques sur un microorganisme de l'atmosphère, le *Streptothrix Foersteri*, Cohn.

„ 12. DOWDESWELL: Sur quelques phases du développement du microbe du choléra.

Tome III.

No. 1. BUSQUET: Étude morphologique d'une forme d'Achorion, l'*Achorion Arloinii*, champignon du favus de la souris (cont. in Nos. 2–3).

„ 2. HANSEN: Nouvelles recherches sur la circulation de *Saccharomyces apiculatus* dans la nature.

Association Française pour l'avancement des Sciences—Compte Rendu de la 18me session. (Paris, 1889.)

Partie 2, Notes et Mémoires.

BATTANDIER: Notes sur quelques genres de la famille des Synanthérées.

BONNET ET MAURY: Étude sur le *Warionia Saharae*, Benth. et Coss.

Association Francaise pour l'avancement des Sciences (*continued*).

GAY: Sur quelques plantes intéressantes, rares ou nouvelles, de la flore d'Algérie et spécialement de la région médéenne.

TRABUT: Les hybrides du *Quercus suber*, principalement en Algérie, *Q. Numidica* et *Q. Kabylica*.

QUÉLET: Quelques espèces critiques ou nouvelles de la flore mycologique de France.

CLOS: Quelques cas de stérilité de plantes.

BATTANDIER: Expérience sur la valeur du sens de l'enroulement des gousses comme caractère spécifique dans le genre *Medicago*.

MALINVAUD: Un bouquet de Roses des environs de Provins.

VUILLEMIN: Antibiose et symbiose.

BONNET: Plantes du poste optique de Founassa (Sud Oranais).

MER: Particularités de végétation que présentent dans les Vosges les *Hypoderma nervisequum* et *macrosporum* ainsi que le *Chrysomixa abietis*.

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Fasc. 2. DANGEARD: Recherches histologiques sur les champignons (continued in Fasc. 3). (Plates III and IV.)

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PAUMELLE: Compte rendu de l'excursion à Gonfreville-l'Orcher près Harfleur (26 mai 1889)—Botanique.

BERGEVIN: Note sur une forme anormale du *Leucanthemum vulgare*, Lam.

NIEL: Le *Daucus Carota*, L., et ses variétés: *gummifer*, *hispidus*, *maritimus*.

LETTACQ: Note sur une nouvelle station du *Lathraea squamaria*, L., dans le département de l'Orne.

BALLÉ: Note sur la forme anomale de l'*Aspidium filix-mas*.

BERGEVIN: Note sur un cas de Synanthie du *Digitalis purpurea*.

SCHLUMBERGER: Note sur la germination du blé de momie.

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BERGEVIN; Partitions anomales du Rachis chez les Fougères (illustr.).

———: Liste des plantes reçueillies pendant l'excursion de la Société aux environs d'Elbeuf, le 15 septembre 1889.

D'YOOVIE: Sur la culture de la Moullé.

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TOUSSAINT: Notice sur quelques stations de plantes aux environs de Rouen, vers la fin du XVIIIe siècle.

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VUILLEMIN: Sur la maladie du Peuplier pyramidal. p. xvii.

HARMAND: Observations relatives à la Flore lichénique de la Lorraine. p. 15.

LEMAIRE: Liste des Desmidiées observées dans quelques lacs des Vosges et aux environs d'Etival. p. 27.

FLICHE: Note sur les Tufs et les Tourbes de Lasnez, près de Nancy. pp. xix, 134.

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MUSSET: Métamorphose progressive des plantes hermaphrodites en plantes unisexuelles. p. 5.

———: Mutation et torsion de l'épi du *Zea Maïs*. p. 23.

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„ X. HÉRAIL: Recherches sur l'anatomie de la tige des Dicotylédones.

„ „ FORTUNÉ: Des Violariées (étude spéciale du genre *Viola*).

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———: Plantes de la famille des Papilionacées dont les fruits simulent divers animaux.

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RENAULT: Notice sur une Lycopodiacée arborescente du terrain houiller du Brésil. (Pl. IX.)

GILLOT ET LUCAND: Catalogue raisonné des Champignons supérieurs (Hymenomycètes) des environs d'Autun et du département de Saône-et-Loire. (Pl. X, XI.)

RENAULT: Sur un noveau genre fossile de tige cycadéenne.

———: Sur la structure comparée du faisceau foliaire des Lépidodendrons et des Sigillaires.

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„ — MIEG, BLEICHER ET FLICHE: Contribution à l'étude du terrain tertiaire d'Alsace et des environs de Mulhouse. (Pl. VI.) (Continued in No. 6.)

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LETACQ: Les spores des Sphaignes d'après les récentes observations de M. Warnstorf.

———: Notes sur les mousses et les hépatiques des environs de Bagnoled et observations sur la végétation bryologique.

LÉGER: Notes sur des germinations anormales d'*Acer platanoides*.

LE ROUX: Le mécanisme de la pollinisation chez certaines Nyctaginées.

LIGNIER: Observations biologiques sur le parasitisme du *Thesium divaricatum*, var. *humifusum*.

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No. 188. GOSNE: Flore de la Somme.
„ 189. BRANDICOURT: Herborisations de 1889 (continued in No. 190).
„ 191. COPINEAU: La desiccation des Plantes en voyage.
„ 195. Clé dichotomique pour reconnaître les bois de notre région.
„ 196. GUILBERT: Contributions à la flore locale.
„ — COPINEAU: Tératologie végétale.
„ 198. GOSNE: Florules de Sailly-Bray, d'Hautebut et du Hable d'Ault.
„ 207. BRANDICOURT: Herborisations de 1888.
„ — ———— : Relations entre les Fourmis et les Plantes.

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Tome V (*continued*).

Fasc. 4. COSTANTIN: Note sur la culture de quelques champignons (*continued*).
„ — SACCARDO: Notes Mycologiques. (Pl. XIV.)
„ — PRILLIEUX ET DELACROIX: Note sur quelques champignons parasites nouveaux ou peu connus.
„ — ————: Note sur le Black Rot.
„ — PATOUILLARD: Les conidies du *Solenia anomala*.
„ — HUYOT: Note sur les causes des monstruosités dans les Champignons.
„ — ———: Note sur la Comestibilité du *Clitocybe inversa*.
„ — BOURQUELOT: Les Hydrates de Carbone chez les Champignons. I—Matières sucrées.
„ — ROLLAND: Excursion à Zermatt (Suisse). Cinq Champignons nouveaux. (Pl. XIV *bis* and XV.)
„ — BOYER: Sur une Monstruosité du *Clitocybe nebularis*. (Pl. XVI.)
„ — MÉNIER: Note sur deux nouvelles Lépiotes. (Pl. XVII and XVIII.)

Tome VI.

Fasc. 1. BOURQUELOT: Recherches sur les matières sucrées dans les Champignons (*continued*) (continued in Fasc. 3 and 4).
„ — DELACROIX: Note sur quelques Champignons inférieurs nouveaux recueillis à l'Exposition coloniale.
„ — BOUDIER: Des Paraphyses, de leur rôle et de leurs rapports avec les autres éléments de l'Hyménium.
„ — PATOUILLARD: Sur la place du genre *Favolus* dans la classification.
„ 2. BOUDIER: Observations sur la végétation fongique aux environs de Paris en 1889.
„ — PRILLIEUX: Le *Pachyma cocos* dans la Charente-Inférieure.
„ — ————— ET DELACROIX: Note sur le *Dothiorella Pitya*. (Pl. XV.)
„ — DELACROIX: Espèces nouvelles de Champignons inférieurs. (Pl. XV.)
„ — LEGUÉ: Note sur le *Pleurotus olearius*.
„ — DE SEYNES: Un *Ceriomyces* nouveau.
„ — ROLLAND: Une nouvelle espèce de *Stysanus*.
„ — PATOUILLARD: *Dussiella*, nouveau genre d'Hypocréacées.

Bulletin de la Société Mycologique de France (*continued*),

Fasc. 2. PRILLIEUX ET DELACROIX: I.—La maladie du pied du blé. (Pl. XVI.)
II.—Sur une nouvelle espèce de *Physalospora* et sur le *Phoma Brassicae*. (Pl. XVI.)

„ — GÉRARD: Matières grasses de deux Champignons hyménomycètes (continued in Fasc. 3).

„ 3. PRILLIEUX ET DELACROIX: Parasitisme du *Botrytis cinerea* et du *Cladosporium herbarum*.

„ — ——————: Note sur l'*Uromyces scutellatus*, Schrank.

„ — ——————: Note sur le *Dothiorella robiniae*, n. sp.

„ — DELACROIX: Espèces nouvelles de Champignons inférieurs.

„ — ——————: Note sur l'*Haplographium toruloides*, Fres.

„ — BOUDIER: Sur le pédicelle des spores des *Bovista* et les filaments stériles du capillitium.

„ 4. PATOUILLARD: Le genre *Podaxon*. (Pl. XVII.)

„ — LUDWIG: Sur une forme nouvelle tératologique du *Paxillus involutus*.

„ — BOUDIER: Note sur une anomalie morchelloide du *Cortinarius scutulatus*, Fr. (Pl. XVIII.)

„ — PRILLIEUX ET DELACROIX: Sur deux parasites du sapin pectiné.

„ — ——————: Sur quelques champignons parasites nouveaux. (Pl. XX.)

„ — DELACROIX: Quelques espèces nouvelles de champignons inférieurs. (Pl. XX.)

Bulletin de la Société Philomathique de Paris. (Paris, 1890.) Tome II.

No. 2. DEVAUX: Méthode nouvelle pour l'étude des atmosphères internes des végétaux.

„ — FRANCHET: Diagnoses d'espèces nouvelles du genre *Chrysosplenium*.

„ 3. DRAKE DEL COSTILLO: Contribution à la flore du Tonkin (Cyrtandracées).

Bulletin Mensuel de la Société Linnéenne de Paris. (1889–90.)

No. 101. BAILLON: Sur une Asclépiadacée comestible du Laos.

„ — ————: Sur le *Craspidospermum*.

„ — ————: Sur le groupe des Taccacées.

„ 102. DURAND: Sur la fleur de l'*Aspidistra punctata* (*continued*).

„ — BAILLON: Liste des plantes de Madagascar (*continued*) (continued in Nos. 107, 8).

„ — ————: Sur trois *Stephanotis* néo-calédoniens.

„ — ————: Le *Pentanura* du Yunnan.

„ — ————: L'organisation de la fleur et du fruit de l'*Harpagonella*.

„ — ————: Sur l'organisation des *Humbertia*.

„ — ————: Les fleurs mâles du *Podoon* (*continued*).

„ 103. ————: Le *Bonamia* de Dupetit-Thouars.

„ — ————: Sur l'*Ellisiophyllum*.

„ — ————: Les fleurs du *Sacellium lanceolatum*, H. B. K.

„ — ————: Sur un nouveau *Thenardia* du Mexique.

„ — ————: La préfloraison de la corolle des Dichondrées.

„ — ————: Sur plusieurs Acanthacées à fleurs involucrées.

„ — ————: Sur le Pambotano.

„ — ————: Les quatre divisions stylaires du *Cleonia*.

„ 107. ————: Sur le *Neolindenia* (continued in No. 109).

Bulletin Mensuel de la Société Linnéenne de Paris (*continued*).

No. 107. BAILLON: Sur plusieurs Ruelliées exceptionelles.
„ — ——— : Le fruit du *Santalina*.
„ — ——— : La fleur et la graine de l'*Hottonia palustris*.
„ — ——— : Sur les caractères des *Hansteinia* et *Stenostephanus*.
„ — ——— : Sur le *Strophantus hispidus*.
„ 108. ——— : Reconstitution de la famille des Boraginacées (*continued*).
„ 109. HEIM: Sur un type nouveau de Diptérocarpées.
„ — BAILLON: Observations sur quelques nouveaux types du Congo (continued in No. 110).
„ 110. ——— : Remarques sur les Ternstrœmiacées (*continued*).
„ — ——— : Les affinités des Verbénacées.
„ — ——— : Les fleurs de l'*Anisacanthus virgularis*, Nees.
„ — ——— : Sur un *Lysinema* monstrueux.
„ — ——— : Sur un nouveau *Baillonia*.
„ 111. ——— : Observations sur les Sapotacées de la Nouvelle-Calédonie (continued in No. 112).

Bulletin Scientifique de la France et de la Belgique. (Paris, 1889–90.)

Tome XX.

GIARD: Sur la transformation de *Pulicaria dysenterica* en plante dioique (illust.).
———: Note sur *Sorosporella agrotidis* de Sorokin.
———: Sur quelques types remarquables de Champignons Entomophytes (illust.).
——— ET MANGIN: Notes sur la castration parasitaire de *Melandryum vespertinum* (*Lychnis dioica*).

Tome XXI.

BILLET: Contribution à l'étude de la Morphologie et du développement des Bactériacées. (Plates I–IX.)
LIGNIER: Recherches sur l'anatomie des organes végétatifs des Lécythidées, des Napoléonées, et des Barringtoniées. (Plates X–XIII.)

Tome XXII, Partie 1.

WALDEYER: De la caryocinèse et de ses relations avec le processus de la fécondation. (Plate V.) (Traduit et annoté par P. Garnault.)
HECKEL: Sur les fleurs souterraines de *Linaria spuria*, Mill. et de *Polygonum aviculare*, L.
LUSTRAC: Sur un fait de castration parasitaire du *Zea maïs* (illustr.).
DEBRAY: Sur la structure et le développement des *Chylocladia*, *Champia* et *Lomentaria*, II. (Illustr.)

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No. 1. BOULLER: Trèfles virescents et *Bidens* hybrides.
„ — MOREL: *Senecio cordatus* à la Dent d'Oche.
„ — VEULLIOT: *Tulostoma mammosum* de la Côte-d'Or.
„ — ROUX: Herborisation au Seneppé.
„ — SAINT-LAGER: Variabilité de l'espèce.
„ — ROUX: Le Champignon du muguet.
„ 2. GARCIN: *Chara fragilis* à Décines.
„ — ROUX: Herborisation à la Salette.
„ — GARCIN: Anomalies du *Lonicera Periclymenum*.

Bulletin trimestriel de la Société botanique de Lyon (*continued*).

No. 2. GÉRARD: La famille des Renonculacées.
„ 3. PRUDENT: Récoltes de Diatomées.
„ — BLANC: Herborisation au mont Salève.
„ — VIVIAND-MOREL: *Liparis Loeselii* à Décines—*Stellera Passerina* à Villeurbanne.
„ — BEAUVISAGE: Herborisations à Perrache.

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DEBEAUX: Description d'une espèce nouvelle de *Centaurea*.
LABORIE: Contribution à la flore du département du Tarn (*continued*).
DEBEAUX: Les régions botaniques de l'arrondissement d'Oran.

Procès Verbaux.

BRÆMER: Un nouveau réactif histo-chimique des tannins.
DEBEAUX: Notes sur quelques plantes rares ou peu connues de la flore oranaise.
LABORIE: Sur la station de quelques plantes rares des environs de Toulouse.

Comptes Rendus Hebdomadaires de la Société de Biologie. (Paris, 1890.) Série 9. Tome II.

No. 1. BUCKET: Les lichens attaquent le verre et, dans les vitraux, semblent préférer certaines couleurs.
„ 2. WURTZ: De l'action bactéricide du blanc d'œuf.
„ 5. GUIGNARD: Sur la localisation, dans les amandes et le laurier-cerise, des principes qui fournissent l'acide cyanhydrique.
„ 7. RODET ET ROUX: Sur les relations du bacillus Coli communis avec le bacille d'Eberth et avec la fièvre typhoïde.
„ — GALIPPE: Présence de micro-organismes dans les végétaux.
„ 8. RODET: Sur la recherche du bacille typhique dans l'eau.
„ — LEROY: Etudes biologiques sur le microbe de l'érysipèle.
„ 9. GUIGNARD: Sur une nouvelle bactériacée marine, le *Streblotrichia Bornetii*.
„ 10. NETTER: Coexistence du pneumocoque et du *Staphylococcus pyogenes aureus*.
„ 11. MÉGNIN: Différence spécifique entre le champignon de la teigne des poules et celui de la teigne faveuse, démontrée par la culture.
„ 14. RODET ET COURMONT: Sur les microbes de l'ostéomyélite aiguë juxta-épiphipaire.
„ — GIARD: Nouvelles recherches sur les bactéries lumineuses pathogènes.
„ 16. PONCET: Deuxième note sur les microbes de l'eau de Vichy.
„ 18. COURMONT ET JABOULAY: Sur les microbes de l'ostéomyélite aiguë infectieuse (*v.* also No. 28).
„ 19. LANNELONGUE ET ACHARD: Des ostéomyélites à streptocoques.
„ 21. ———————: Sur la distinction des staphylocoques blanc et orangé d'après la virulence et le pouvoir chromogène.

Comptes Rendus Hebdomadaires de la Société de Biologie (*continued*).

No. 23. CASSEDEBAT: Notes sur les bacilles pseudo-typhiques trouvés dans les eaux de rivière.

„ 26. GLEY ET CHARVIN: Tumeurs et Microbes.

„ — KROGIUS: Note sur un Bacille Pathogène (*Urobacillus liquefaciens septicus*) trouvé dans les urines pathologiques.

„ 29. BOURQUELOT: Sur la présence et la disparition du tréhalose dans les Champignons.

„ 30. OLIVIER: Sur les connectifs intercellulaires du protoplasme chez les végétaux.

„ 32. THÉLOHAN: Recherches sur le développement des spores chez les myxosporidies.

„ 36. JUMELLE: La vie des Lichens pendant l'hiver.

Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences. (Paris.) Tome CX.

No. 2. HECKEL: Sur l'utilisation et les transformations de quelques alcaloïdes dans la graine pendant la germination.

„ 3. VIOLA: Sur le développement du Pourridié de la Vigne et des arbres fruitiers.

„ 4. GIRARD: Recherches sur la culture de la pomme de terre industrielle et fourragère.

„ 5. DANGEARD: Le mode d'union de la tige et de la racine chez les Gymnospermes.

„ 6. MANGIN: Sur la substance intercellulaire.

„ — CLAUDEL: Sur la localisation des matières colorantes dans les téguments séminaux.

„ 7. LORTET ET DESPEIGNES: Recherches sur les microbes pathogènes dans les eaux filtrées du Rhône.

„ — LINOSSIER ET ROUX: Sur la nutrition du Champignon du muguet.

„ — BONNIER: Cultures expérimentales dans les hautes altitudes.

„ 8. CHATIN: Contribution à l'étude chimique de la Truffe (continued in No. 9).

„ — GRIFFITHS: Sur une nouvelle ptomaïne de putréfaction, obtenue par la culture du *Bacterium Allii*.

„ — GESSARD: Sur les fonctions chromogènes du bacille pyocyanique.

„ 9. SCHLŒSING: Sur l'absorption de l'ammoniaque de l'atmosphère par la terre végétale (continued in No. 10).

„ — PAGNOUL: Influence des feuilles et de la lumière sur le développement des tubercules de la pomme de terre.

„ — GUIGNARD: Sur la localisation dans les plantes, des principes qui fournissent l'acide cyanhydrique.

„ — TRABUT: Renforcement de la sexualité chez un hybride (*Ophrys Tenthredinifero-Scolopax*).

„ 11. BERTHELOT: Observations sur les réactions entre la terre végétale et l'ammoniaque atmosphérique (*v.* No. 12).

„ — GUIGNARD: Sur la formation et la différenciation des éléments sexuels qui interviennent dans la fécondation.

„ — PRUNET: Sur la structure comparée des nœuds et des entre-nœuds dans la tige des Dicotylédones.

„ 12. MANGIN: Sur la callose, nouvelle substance fondamentale dans la membrane des cellules des végétaux.

„ 13. GUIGNARD: Sur le mode d'union des noyaux sexuels dans l'acte de la fécondation.

Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences (*continued*).

No. 13. LAGERHEIM: Sur un nouveau parasite dangereux de la Vigne, *Uredo Vialae.*

" 15. CASSEDEBAT: Sur un bacille pseudo-typhique trouvé dans les eaux de rivière.

" — BABÈS: Sur les microbes de l'hémoglobinurie du bœuf.

" — RENAULT: Sur une nouvelle Lycopodiacée houillière (*Lycopodiopsis Derbyi*).

" 17. MARION: Sur le *Gomphostrobus heterophylla*, Conifère prototypique du Permien de Lodève.

" — PAGNOUL: Expériences relatives aux pertes et aux gains d'azote éprouvés par une terre nue ou cultivée.

" — MAGNIN: Sur la castration parasitaire de l'*Anemone ranunculoides* par l'*Aecidium leucospermum.*

" 18. MUNTZ: Du rôle des engrais verts comme fumure azotée.

" 19. SAPORTA: Sur les retards de la frondaison en Provence, au printemps de 1890.

" — WINOGRADSKY: Sur les organismes de la nitrification.

" 21. MARION: Sur la flore turonienne des Martigues (Bouches-du-Rhône).

" — VASSEUR: " " " " " "

" 22. MAGNIN: Sur la castration androgène du *Muscari comosum*, Mill. par l'*Ustilago Vaillantii*, Tul. et quelques phénomènes remarquables accompagnant la castration parasitaire des Euphorbes.

" 23. MUNTZ: Sur la décomposition des engrais organiques dans le sol.

" — BRANDZA: Recherches sur le développement des téguments séminaux des Angiospermes.

" 24. RUSSELL: Recherches sur les bourgeons multiples.

" — BARTET: De l'influence exercée par l'époque de l'abatage sur la production et le développement des rejets de souches dans les taillis.

" 25. TIMIRIAZEFF: Enregistrement photographique de la fonction chlorophyllienne par la plante vivante.

Tome CXI.

No. 3. VILLE: De la sensibilité des plantes, considérées comme de simples réactifs.

" — PRILLIEUX ET DELACROIX: La gangrène de la Tige de la pomme de terre, maladie bacillaire.

" 4. GUIGNARD: Sur la localisation des principes qui fournissent les essences sulfurées des Crucifères.

" 5. DEGAGNY: Sur la division cellulaire chez le *Spirogyra orthospira* et sur la réintégration des matières chromatiques refoulées aux pôles du fuseau.

" — DE L'ÉCLUSE: Le traitement du Black-Rot.

" 6. SAUVAGEAU: Sur une particularité de structure des plantes aquatiques.

" — DUBOIS: Sur le prétendu pouvoir digestif du liquide de l'urne des Népenthées.

" — BRANDZA: Recherches anatomiques sur les hybrides.

" 7. TRÉCUL: Ordre d'apparition des premiers vaisseaux dans les fleurs de quelques *Tragopogon* et *Scorzonera.*

" 8. DUBOIS: Nouvelles recherches sur la production de la lumière par les animaux et les végétaux.

" — LEBESCONTE: Sur la présence du carbonifère en Bretagne.

Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences (*continued*).

No. 9. BONNIER: Influence des hautes altitudes sur les fonctions des végétaux.
„ — JUMELLE: Sur l'assimilation chlorophyllienne des arbres à feuilles rouges.
„ — DANGEARD: Sur les oospores formées par le concours d'éléments sexuels plurinucléés.
„ 11. SÉRULLAS: Sur l'*Isonandra Percha* ou *I. Gutta.*
„ — RAVAZ: Recherches sur le bouturage de la Vigne.
„ 12. JUMELLE: Influence comparée des anesthésiques sur l'assimilation et la transpiration chlorophylliennes.
„ 14. PAGNOUL: Expériences de culture du blé dans un sable siliceux stérile.
„ 15. BOURQUELOT: Sur la présence et la disparition du tréhalose dans les champignons.
„ — CURTEL: Recherches physiologiques des enveloppes florales.
„ 16. BOURQUELOT: Les matières sucrées chez les champignons.
„ 17. PRILLIEUX: La pourriture du cœur de la betterave.
„ 19. THÉLOHAN: Nouvelles recherches sur les spores des Myxosporidies.
„ 20. SCHLŒSING FILS ET LAURENT: Sur la fixation de l'azote gazeux par les légumineuses.
„ — BERTHELOT: Observations sur la Note précédente.
„ — LAURENT: Sur le microbe des nodosités des légumineuses.
„ 22. SAPORTA: Sur de nouvelles flores fossiles, observées en Portugal, et marquant le passage entre les systèmes jurassique et infracrétacé.
„ — BASTIT: Influences comparées de la lumière et de la pesanteur sur la tige des Mousses.
„ — LÉGER: Sur la présence de laticifères chez les Fumariacées.
„ 24. GUIGNARD: Sur la localisation des principes actifs dans la graine des Crucifères.
„ — MANGIN: Sur la structure des Péronosporées.
„ — PRILLIEUX: Anciennes observations sur les tubercules des racines des Légumineuses.

Diatomiste, Le. (Paris, 1890.)

No. 1. Diatomées rares ou nouvelles (continued in Nos. 2 and 3).
„ — Nomenclature des Diatomées.
„ 2. *Dictyoneis*, n. gen., P. T. Cleve.
„ — BELLOC: Diatomées observées dans quelques lacs du Haut Larboust, Région d'Oô.
„ 3. TEMPÈRE: Recherche et récolte des Diatomées.
„ — DUTERTRE: Sur la photographie des Diatomées.

Journal de Botanique. Année 4. (Paris, 1890.)

No. 1. CAMUS: Orchidées hybrides.
„ — GUIGNARD: Sur la localisation dans les Amandes et le Laurier-cerise des principes qui fournissent l'acide cyanhydrique (continued in No. 2).
„ — PATOUILLARD: Contributions à la flore mycologique du Tonkin.
„ 2. BALANSA: Catalogues des Graminées de l'Indo-Chine française (continued in Nos. 6, 7, 9).
„ — HUE: Lichens de Canisy (Manche) et des environs (continued in Nos. 6, 8, 11, 14, 16).
„ 3. SAUVAGEAU: Observations sur la structure des feuilles des plantes aquatiques (continued in Nos. 4, 6, 7, 9, 10, 12, 13).

Journal de Botanique (*continued*).

No. 3. HARIOT: Notes sur le genre *Trentepohlia*, Martius (*continued*) (continued in Nos. 5, 9, 10).

" 9. BONNET: Lettres et documents inédits pour servir à l'histoire de la Botanique au XVIII^e^ siècle (continued in Nos. 8, 12).

" 8. CASTILLO: Contributions à l'étude de la Flore du Tonkin.

" 10. PATOUILLARD: Fragments mycologiques (continued in No. 14).

" 11. BESCHERELLE: Nouvelle contribution à la Flore bryologique du Tonkin.

" — DOULIOT: Sur le développement de la tige des Conifères.

" 12. POIRAULT: Les Urédinées et leurs plantes nourricières (continued in Nos. 13, 17, 19).

" 14. PRUNET: Sur les bourgeons dormants des plantes ligneuses dicotylédones.

" 15. SAUVAGEAU: Sur la feuille des Hydrocharidées marines (continued in No. 16).

" 16. PARISOT: Herborisation à Montfort-l'Amaury et à Gambaiseuil.

" 17. FRANCHET: Sur quelques plantes rares ou nouvelles de la Flore du nord de la Chine (continued in No. 15).

" 18. SAUVAGEAU: Sur la structure de la feuille des genres *Halodule* et *Phyllospadix*.

" 19. FEER: Recherches littéraires et synonymiques sur quelques Campanules (continued in No. 21).

" 20. GOMONT: Essai de classification des Nostocacées homocystées.

" — KARSTEN ET HARUT: Fungilli imperfecti novi.

" — MOROT: *Dobinea* et *Podoon*.

" 21. VAN TIEGHEM: Remarques sur la structure de la tige des Prêles.

" 22. GUIGNARD: Recherches sur la localisation des principes actifs des Crucifères (continued in Nos. 23, 24).

" — DE CANDOLLE: Les Pipéracées de l'Ecuador, de la Nouvelle-Grenade et du Péron, de la collection de M. Ed. André.

" — LECOMTE: Sur le rôle du liber.

" 23. VAN TIEGHEM: Remarques sur la structure de la tige des Ophioglossées.

" — CHRIST: Une nouvelle Fougère au Tonkin français, *Cyathea Bonii*, n. sp,

" 24. VAN TIEGHEM: Péricycle et périderme.

Journal de Micrographie. 1890. (Paris.)

No. 1. VRONCOUR: Notes diatomologiques.

" 2. PETIT: Diatomées nouvelles des lignites de Sendai (Japan).

" — WEVRE: La Lignine.

" 3. VIALA: Développement du Pourridié de la Vigne et des arbres fruitiers.

" 4. GONZALEZ: Une nouvelle plante insectivore (*Aristolochia grandiflora*).

" 5. PETIT: Notes sur les Diatomées fossiles du Japon.

" 6. LAGERHEIM: Un nouveau parasite dangereux de la vigne.

" 7. COX: Les Diatomées, leur nutrition et leurs mouvements (continued in No. 8).

" — GUIGNARD: Sur le mode d'union des noyaux dans la fécondation.

" — MANGIN: Sur la callose, nouvelle substance fundamentale des membranes.

" 8. DEGAGNY: Sur la division cellulaire chez le *Spirogyra orthospira*.

" 9. ONDERDONK: Les mouvements des Diatomées.

" 11. MARCHAND: Définition du mot *Cryptogame*: Histoire de la découverte de la Sexualité végétale.

" — PETICOLAS: Notes sur le dépôt fossile de Diatomées marines d'Atlantic City.

L'Orchidophile. 10e Année. (Paris, 1890.)

No. 104. Voyage aux montagnes de Roraima de M. Seidel (continued in No. 106).
„ — *Aerides Houlletianum* (with coloured plate).
„ — De la variabilité des formes d' *Odontoglossum Alexandrae.*
„ 105. *Cypripedium Minerva*, n. hyb.
„ — *Laelia pumila* (with coloured plate).
„ — Nomenclature des Orchidées.
„ — Les Cypripedium.
„ 106. Le *Cattleya Schroederae.*
„ — Les Masdevallias (with coloured plate of *M. Harryana*).
„ 107. *Odontoglossum Schlumbergeri.*
„ — *Coelogyne Massangeana.*
„ — Les *Cattleya Mossiae.*
„ — Les *Phalaenopsis Schilleriana.*
„ — *Cypripedium Binoti* (with coloured plate).
„ — Les Vandas.
„ 108. *Dendrobium atroviolaceum*, n. sp.
„ — Quelques Orchidées nouvelles.
„ — Les *Laelia purpurata.*
„ — Les engrais pour les Orchidées.
„ — *Cypripedium Spicerianum* (with coloured plate).
„ 109. Dévastation de la Flore Brésilienne.
„ — Les *Cattleya Mossiae.*
„ — *Miltonia Bluntii*, var. *Lubbersiana* (with coloured plate).
„ — ROMAN : Études sur le traitement des Orchidées par les engrais minéraux (continued in No. 110).
„ 110. *Odontoglossum Harryanum* (with coloured plate).
„ 111. *Habenaria militaris.*
„ — *Renanthera matutina.*
„ — *Laelia juvenilis* (with coloured plate).
„ — Les Thunias.
„ 112. Culture du *Phajus tuberculosus.*
„ — *Cypripedium Selligerum Majus* (with coloured plate).
„ — Les Orchidées de Panama.
„ 113. *Houlletia Brocklehurstiana.*
„ — *Dendrobium nobile* et *D. nobile album* (with coloured plate).
„ — *Vanda coerulea* (with coloured plate).
„ 114. *Cattleya Alberti* (with coloured plate).
„ — *Calanthe veratrifolia* et ses variétés.

Mémoires de l'Académie des Sciences de Toulouse. 9e Série. Tome II. (Toulouse, 1890.)

LAVOCAT : Reproduction végétale et animale.

CLOS : Individualité des faisceaux fibro-vasculaires des appendices des plantes.

Mémoires de la Société Géologique de France. Paléontologie. Tome I. (Paris, 1890.) Fasc. III.

SAPORTA : Le *Nelumbium provinciale.* (Pl. XII–XIV.)

Mémoires de la Société Linnéenne du Nord de la France. Tome VII. 1886–88. (Amiens, 1889.)

GOSNE: Supplément à la Flore de la Somme.

———: Additions au catalogue des Muscinées de la Somme.

Mémoires de la Société Nationale des Sciences Naturelles et Mathématiques de Cherbourg. Tome XXVI. (Paris, 1889.)

BORNET ET FLAHAULT: Tableau synoptique des Nostocacées filamenteuses hétérocystées.

CORBIÈRE: Muscinées du département de la Manche (with Plate).

Nouvelles Archives du Muséum d'Histoire Naturelle. (Paris, 1890.) Tome II.

FRANCHET: Monographie du genre *Chrysosplenium*.

Revue Biologique du Nord de la France (Lille). Année 2 (*continued*).

No. 6. FOCKEN: Deuxième Liste des Galles observées dans le Nord de la France (*continued*) (continued in No. 11 and Ann. 3, No. 1).

„ 7. ———: Observations sur la Galle du *Sinapis arvensis*. (Illustrated.)

„ 10. ———: Notes sur la Galle de l' *Hormomyia fagi* (Hart.) (Illustrated.)

Revue Bryologique. (Le Mans, 1890.)

No. 1. CORBIÈRE: Les Fossombronia du département de la Manche.

„ — JAMESON: *Rhabdoweisia crenulata*.

„ — MORIN: Mousses des environs de Dinan.

„ — PHILIBERT: Études sur le péristome (*continued*) (continued in Nos. 2, 3).

„ 2. CARDOT: *Hypnum circinale* et un *Grimmia* hybride.

„ — PHILIBERT: *Brachythecium latifolium*.

„ — GRAVET: Les fibres des cellules médullaires des *Sphagna cuspidata*.

„ — CORBIÈRE: *Grimmia orbicularis*, var. *Therioti* et *Leptobarbula berica*.

„ — PAYOT: Supplément au Catalogue du Mont-Blanc.

„ 3. PHILIBERT: Sur la fructification du *Marsupella revoluta*.

„ — THÉRIOT: *Fissidens minutulus*.

„ — ——— : Notes sur la flore de la Sarthe.

„ — HUSNOT: Les *Philonotis* dioïques.

„ 4. VENTURI: Barbulae rurales.

„ — AMANN: *Mnium subglobosum*.

„ — PHILIBERT: *Bryum Roellii*.

„ — RAVAUD: Guide du Bryologue et du Lichénologue aux environs de Grenoble (*continued*).

Revue de Botanique (Toulouse). Tome VIII.

No. 85. OLIVIER: Etude sur les *Pertusaria*.

„ — HY: Sur les caractères généraux des Characées et eur importance taxonomique (continued in No. 86).

„ 86. GAY: Note sur quelques plantes intéressantes de la flore d'Algérie.

„ — GÉRARD: Notes sur quelques plantes des Vosges, additions et rectifications (continued in Nos. 87–90, 92–96).

„ 87. FEUILLEAUBOIS: Les Champignons de la France, analyse du 12e fascicule.

„ — LUSTRAC: Un curieux habitat du *Penicillium glaucum*.

„ 88. D'AYMERIC: Excursion botanique au pic Saint-Barthélemy.

„ — DEBEAUX: Plantes nouvelles de l'Algérie et du bassin méditerranéen.

Revue de Botanique (*continued*).

No. 88. GUÉRIN: Expériences sur la germination et l'implantation du gui (continued in No. 89).

„ 89. AUBOURG: Plantes intéressantes observées aux environs d'Aniane (Hérault).

— „ DEBEAUX: Note sur la *Cenchrus echinatus*, L.

„ 90. COPINEAU: *Vicia villosa*, Roth, et *Cracca villosa*, Gg.

„ — D'AYMERIC: Une espèce nouvelle pour les Pyrénées (*Hieracium glanduliferum*, Hoppe).

„ — BEL: Monographie des Rosiers du Tarn (continued in No. 91).

„ — GAY: Une importante anomalie du *Gagea fibrosa*.

„ — DOUMERGUE: Herborisations Oranaises (continued in Nos. 92, 94, 95).

„ 91. RENAULD: Le *Brachythecium latifolium*, Lindl. dans les Pyrénées.

„ — CHEVALLIER: Contribution à la flore de la Sarthe (continued in No. 92).

„ — GUÉRIN: Anomalies du *Gagea arvensis*, Schultz.

„ — GAY: Sur le *Bellis silvestris*.

„ 95. DEBEAUX: Observations sur l'*Arenaria spathulata*, Desf.

Revue Générale de Botanique (Paris).

Tome I (*continued*).

No. 10. COSTANTIN: Sur les variations des *Alternaria* et des *Cladosporium* (*concluded*). (Illustrated.)

„ — SEIGNETTE: Recherches sur les tubercules (*continued*). (Illustrated.) (Continued in Nos. 11 and 12.)

„ 11. POULSEN: Une nouvelle phanérogame sans chlorophylle (*Thismia Glaziovii*).

„ — BONNIER: Observations sur les Renonculacées de la flore de France (*continued*). (Illustrated.) (Continued in No. 12.)

„ 12. MASCLEF: Les formes critiques d'Hellébores de la Savoie et du Dauphiné.

„ — DUFOUR: Une nouvelle espèce de *Psathyrella*. (Illustrated.)

Tome II.

„ 13. BATTANDIER ET TRABUT: Description du *Pancratium Saharae*, Cosson (inédit). (Plate 1.)

„ — CARTEL: Recherches physiologiques sur la transpiration et l'assimilation pendant les nuits norvégiennes. (Illustrated.)

„ — FLOT: Recherches sur la structure comparée de la tige des arbres (continued in Nos. 14 and 15).

„ 14. HECKEL: Une nouvelle espèce de l'Afrique tropicale (*Solanum Duchartrei*). (Plate 2.)

„ — LESAGE: Recherches expérimentales sur les modifications des feuilles chez les plantes maritimes. (Illustrated.) (Continued in Nos. 15, 16.)

„ 15. BONNIER: Etude sur la Végétation de la vallée d'Aure (Hautes-Pyrenées) (with map). (Continued in Nos. 16–18.)

„ 16. DAGUILLON: Recherches morphologiques sur les feuilles des Conifères. (Illustrated.) (Continued in Nos. 17–20.)

„ 17. RUSSELL: Recherches sur le développement et l'anatomie des cladodes du petit-houx (*Ruscus aculeatus*).

„ 18. BONNIER: Observations sur les Berbéridées, Nymphéacées, Papavéracées, et Fumariacées de la Flore de France. (Illustrated.)

Revue Générale de Botanique (*continued*).

No. 19. BRANDZA: Recherches anatomiques sur la structure de l'Hybride entre l'*Aesculus rubicunda* et le *Pavia flava*. (Illustrated.)

,, 20. SABLON: Sur le sommeil des feuilles.

,, — RUSSEL: Contribution à l'étude de l'appareil sécréteur des Papilionacées.

,, 21. AUBERT: Sur la répartition des acides organiques chez les plantes grasses. (Illustrated.)

,, — LAGERHEIM: Note sur un nouveau parasite dangereux de la Vigne (*Uredo Vialae*, sp. nov.). (Plate 19.)

,, — DANIEL: Le Tannin dans les Composées.

,, 22. JUMELLE: Influence des Anesthésiques sur la transpiration. (Plate 24.)

,, — BRANDZA: Recherches anatomiques sur les hybrides. (Illustrated.) (Continued in No. 23.)

,, — BONNIER: Observations sur les Nymphéacées et le Papavéracées de la flore de France. (Illustrated.)

,, 23. FRANCHET: Les Bambusées à étamines monadelphes. (Plate 25.)

,, — RUSSELL: Etudes des folioles anormales du *Vicia sepium*. (Illustrated.)

,, 24. BONNIER: Cultures expérimentales dans les Alpes et les Pyrénées. (Plates 20–23.)

,, — POULSEN: Note sur la préparation des grains d'aleurone.

,, — BONNIER: Observations sur les Fumariacées de la flore de France.

Revue Horticole. (Paris, 1890.) Année 62.

No. 1. ANDRÉ: *Sobralia xantholeuca* (with coloured Plate).

,, — CARRIÈRE: *Rosa rugosa*.

,, — ANDRÉ: Les Primevères.

,, 2. ——: Le genre *Narcissus*.

,, — ——: *Pitcairnia Darblayana*.

,, — CARRIÈRE: *Cedrus atlantica fastigiata*.

,, — ——: Variétés de *Montbretia crocosmiaefolia* (with coloured Plate).

,, — ——: *Clerodendron speciosum*.

,, — WEBER: Deux Silènes très recommandables.

,, — MARTINET: Les Azalées nouvelles.

,, 3. TRUFFAUT: Usages des Palmiers.

,, ANDRÉ: *Sedum sempervivum*.

,, — CARRIÈRE: *Papaver croceum* (with coloured plate).

,, 4. VILMORIN: Notes sur quelques *Ficus* du jardin du Hamma.

,, — CARRIÈRE: *Primula obconica*, Hance.

,, — ——: Fraise *Edouard Lefort* (with coloured plate).

,, — ——: Pélargoniums et Géraniums.

,, — ——: Les Céleris.

,, 5. ANDRÉ: *Coffea liberica*.

,, — *Coburgia trichroma*, Herb. (with coloured plate).

,, — CARRIÈRE: *Eulalia japonica univittata*.

,, — ——: Trois plantes à feuilles panachées.

,, — ——: *Abies lasiocarpa pendula*.

,, 6. ——: Deux *Pilocereus* gigantesques.

,, — ——: *Iris reticulata*.

,, — ——: *Ampelovitis* à fruits bleus.

,, — ——: *Abies concolor fastigiata*.

Revue Horticole (*continued*).

No. 7. ANDRÉ: L'arbre du voyageur.
„ — ——— : *Bégonia Adonis* (with coloured plate).
„ — LEQUET : Les fleurs changeantes (continued in Nos. 8, 9).
„ — CONSTANT : Un champignon parasite du Poirier.
„ 8. CARRIÈRE : *Luculia gratissima* (with coloured plate).
„ — ——— : *Vitis acuminata.*
„ — ——— : *Iris Kaempferi.*
„ — ——— : *Phytolacca acinosa.*
„ — DELABARRIÈRE : Greffage du Pêcher sur Abricotier.
„ — ANDRÉ : La Ramie (*Boehmeria utilis*).
„ 9. ——— : *Thunbergia coccinea.*
„ — ——— : Les Prunopsis.
„ — NAUDIN : *Hesperocallis undulata.*
„ — CARRIÈRE : Les Bégonias multiflores (with coloured plate).
„ — MOTET : Essai de classification des Chrysanthèmes de l'Inde.
„ 10. CARRIÈRE : Concombres et Cornichons.
„ — ——— : *Cytisus racemosus.*
„ — ——— : *Salvia Issanchou.*
„ — FRANCHET : Les *Lespedeza* de la Chine occidentale.
„ — BAILLY : *Abies insignis* et *A. Nordmanniana speciosa.*
„ 11. MOREL : Les Gentianes.
„ — CARRIÈRE : Le *Sophora japonica* et sa variété à feuilles panachées.
„ — ——— : *Picea excelsa reflexa.*
„ — NAUDIN : Trois Palmiers de Californie.
„ 12. CARRIÈRE : *Oxera pulchella.*
„ — ANDRÉ : *Robinia Decaisneana rubra.*
„ — TRUFFAUT : Les *Hippeastrum* ou *Amaryllis*, hybridation et culture.
„ 13. ANDRÉ : *Anemopoegma clematideum.*
„ — ——— : *Melica papilionacea.*
„ — ——— : Le *Cattleya Bowringiana* et ses variétés (with coloured plate).
„ — CARRIÈRE : *Planera Kaki.*
——— : Les *Vitis Pseudospina.*
„ 14. ANDRÉ : Influence de la fécondation croisée sur les fruits.
„ — CARRIÈRE : Quelques arbres remarquables à Vichy.
„ — ——— : *Sequoia sempervirens variegata.*
„ — BELLAIR : Le Chrysanthème en France et au Japon avant 1789.
„ 15. NAUDIN : *Eucalyptus Andreana.*
„ — CARRIÈRE : *Molinia Bertini.*
„ — ——— : Rajeunissement des arbres.
„ — ANDRÉ : *Holboellia latifolia* (with coloured plate).
„ — MOTET : Fructification des Violettes.
„ 16. Accidents tératologiques sur une Digitale et un Arum, p. 363.
„ — CARRIÈRE : Une nouvelle japonaiserie : *Aspidium Lepidocaulon.*
„ — ——— : Des sexes dans les Vignes sauvages de l'Extrême Asie.
„ — Anomalie présentée par un œillet.
„ 17. CARRIÈRE : Multiplication de l'*Agave Consideranti.*
„ — ——— : *Tilia argentea orbicularis.*
„ — ——— : *Magnolia Wieseneri.*

Revue Horticole (*continued*).

No. 17. CARRIÈRE: *Iberis sempervirens* flore pleno.
" — LEGROS: *Lachenalia pendula Aureliana* (with coloured plate).
" 18. CARRIÈRE: *Rosa rugosa fimbriata.*
" 19. ———: *Abies Nordmanniana pendula.*
" — ———: *Vitis rutilans* (with coloured plate).
" — ———: *Myrica rubra.*
" — ———: *Punica granatum maximum rubrum.*
" — ———: Prolification indéfinie.
" — ANDRÉ: *Burchellia capensis.*
" — FORNEY: Origine de l'Abricot-Pêche.
" 20. CHARGUERAUD: Les Maronniers qui ne fleurissent.
" — CARRIÈRE: *Spinovitis Davidii.*
" — ———: *Prunus japonica sphaerica* (with coloured plate).
" — ———: *Sambucus racemosa plumosa.*
" — LEQUET: Fleurs sur le vieux bois: le *Goethea cauliflora.*
" 21. Réapparition de la végétation sur une île déserte. (Krakatoa.)
" — ANDRÉ: Le *Cattleya pumila* et ses variétés.
" — CARRIÈRE: *Senecio Ghiesbreghtii* (with coloured plate).
" — ———: Deux variétés remarquables du sureau commun.
" 22. ANDRÉ: *Waldsteinia fragarioides.*
" — ———: Le genre *Sicana* (with coloured plate).
" — HARMAND: Les semis de Pêches américaines.
" — CARRIÈRE: *Euonymus pulchellus foliis variegatis.*
" — ———: *Cryptomeria araucarioides.*
" — VALLERAND: *Begonia erecta atrorubra nana.*
" 23. CARRIÈRE: Un cèdre en Candélabre.
" — ———: *Amorphophallus Titanum.*
" — ———: Un nouveau type de Calcéolaire.
" 24. ANDRÉ: *Eucalyptus calophylla.*
" — WEBER: Moyen d'activer la germination des graines.
" — CARRIÈRE: *Clematis orientalis glauca.*
" — ROTTET: *Lilium Harrisii.*

Revue Mycologique (Toulouse, 1890). 12 Année.

No. 45. ROUMEGUÈRE: Parasitisme du *Tremella Dulaciana*, sp. n. sur l'*Agaricus nebularis.*
" — SOROKINE: Matériaux pour la Flore cryptogamique de l'Asie Centrale (*continued*). (Continued in No. 46.)
" — ROUMEGUÈRE: Fungi selecti exsiccati, LII^e^ centurie.
" — ——— ET BRESADOLA: Nouvelles contributions à la Flore mycologique des Iles Saint-Thomé et des Princes.
" 46. ———: Fungi selecti exsiccati, LIII^e^ cent.
" — ——— ———: Ravages du *Spicaria verticillata*, Cord.
" — GIARD: Emploi des champignons parasites contre les insectes nuisibles.
" — FAUTREY: *Cicinobolus Humuli*, sp. n.
" — KARSTEN ET ROUMEGUÈRE: Champignons nouveaux du Tonkin.
" — ——— ET HARIOT: Fungilli novi.
" 47. BRESADOLA: Champignons de la Hongrie (continued in No. 48).
" — ROUMEGUÈRE: Fungi selecti exsiccati, LIV^e^ cent.

Revue Mycologique (*continued*).

No. 47. ROUMEGUÈRE, KARSTEN ET FAUTREY: Fungi novi vel minus bene cogniti.
„ — HARIOT ET ———; Fungi novi.
„ — ——————: Micromycetes novi.
„ — BRIARD: Champignons nouveaux.
„ — PATOUILLARD: Quelques champignons de la Chine récoltés par M. Delavay.
„ — FERRY: Recherches sur les matières sucrées contenues dans les champignons.
„ — PHILLIPS: Qu'est-ce que le *Peziza albella*, Withering?
„ 48. BOURQUELOT: Les matières sucrées des champignons.
„ — ROUMEGUÈRE: Fungi exsiccati precipue Gallici, LV^e^ cent.
„ — KARSTEN ET HARIOT: Ascomycetes novi.
„ — FERRY: *Amanita valida* et *spissa*, *raphaniodora* et *solida*.
„ — FAUTREY: Nouvelles observations sur le *Cicinobolus Humuli*, n. sp.
„ — BRIARD: Champignons nouveaux, II.

Revue Scientifique du Bourbonnais et du Centre de la France (Moulins, 1889–90).

Année XII (*continued*).

No. 12. LASSIMONNE: La topographie botanique.

Année XIII.

„ 2. BUYSSON: Monographie des Cryptogames vasculaires d'Europe. Filicinées.
„ 3. DUMAS-DAMON: Bryologie du département du Puy-de-Dôme. (Supplément.) (Continued in Nos. 4, 6, 7, and 9.)
„ 4. D'ARTEMARE, BERTHON ET DUMAS-DAMON: Matériaux pour la flore d'Auvergne.
„ 5. GAY: Synopsis de la flore de la Mitidja (continued in Nos. 8, 11).
„ 10. DESJOBERT: Les forêts de Tronçais et Civrais (continued in No. 11).

GERMANY.

Abhandlungen vom Naturwissenschaftlichen Vereine zu Bremen. (Bremen, 1890.) Bd. XI.

Heft 1. BUCHENAU: Die Pflanzenwelt der ostfriesischen Inseln.
„ — FOCKE: Insektenfang durch Pflanzen.
„ — NOBBE: Ueber die Hartschaligkeit von Samen.
„ 2. KLEBAHN: Erster Beitrag zur Schmarotzerpilz-Flora Bremens.
„ — FOCKE: Die *Rubus*-Arten der Antillen.
„ — ———: Versuche u. Beobachtungen über Kreuzung u. Fruchtansatz bei Blütenpflanzen.
„ — ———: Varietäten von *Clivia miniata*.
„ — ———: Die Herkunft der Vertreter der nordischen Flora im niedersächsischen Tieflande.
„ — ———: Beiträge zur nordwestdeutschen Flora.
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" 2. ———: Ueber Widerstandsfähigkeit der Bacterien des Schweinerothlaufs in Reinculturen u. im Fleisch rothlaufkranker Schweine gegen Kochen, Schmoren, Braten, Salzen, Einpökeln u. Räuchern.

" 3. ———: Untersuchungen über die durch das Wachsthum der Cholerabakterien entstehenden chemischen Umsetzungen.

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———: Abnorme Kartoffelbildung.

KRAUSE: Die fremden Bäume u. Gesträuche d. Rostocker Anlagen.

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HEMPEL: Ueber Gallenbildung, p. lvii.

———: Ueber die Pilzkrankheit der Blätter, p. cvii.

KRAMER: Ueber Einfluss von Licht u. Wärme auf die jährliche Periode der Pflanzenentwickelung, p. lxi.

ZIMMERMANN: Ueber die Bakterien der Papilionaceen-Knöllchen.

Abhandlungen.

ZIMMERMANN: Die Bakterien unserer Trink- u. Nutzwässer, insbesondere des Wassers der Chemnitzer Wasserleitung, I. Reihe.

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———: Verzeichniss der bisher in Südbayern beobachteten Peronosporaceen.

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„ — SCHÜTT: Ueber Peridineenfarbstoffe. (Taf. I u. II.)

„ — MIKOSCH: Ueber ein neues Vorkommen geformten Eiweisses. (Taf. III.)

„ 2. HABERLANDT: Die Kleberschicht des Gras-Endosperms als Diastase ausscheidendes Drüsengewebe (with 2 woodcuts).

„ — TSCHIRCH: Ueber durch *Astegopteryx*, eine neue Aphiden-gattung, erzeugte Zoocecidien auf *Styrax Benzoin*, Dryand. (Taf. IV.)

„ 3. BLASS: Untersuchungen über die physiologische Bedeutung des Siebtheils der Gefässbündel.

„ — ASKENASY: Ueber einige Beziehungen zwischen Wachsthum u. Temperatur.

„ — ZIMMERMANN: Ueber die Chromatophoren in panachirten Blättern (Vorläufige Mittheilung).

„ — CAMPELL: Die ersten Keimungsstadien der Makrospore von *Isoëtes echinospora*, Durieu. (Taf. V.)

„ — BOKORNY: Zur Kenntniss des Cytoplasmas. (Taf. VI.)

„ — ———: Notiz über das Vorkommen des Gerbstoffes.

„ — MÄULE: Zur Entwickelungsgeschichte von *Tichothecium microcarpon*, Arn. (Taf. VII.)

„ 4. VOLKENS: Ueber Pflanzen mit lackirten Blättern. (Taf. VIII.)

„ — BACHMANN: Die Beziehungen der Kalkflechten zu ihrem Substrat. (Taf. IX.)

„ — JÄNNICKE: Ueber abnorm ausgebildete Rebenblätter. (Taf. X.)

„ 5. MÜLLER, C.: Ein Beitrag zur Kenntniss der Formen des Collenchyms. (Taf. XI.)

„ — MAGNUS: Ueber die in Europa auf der Gattung *Veronica* auftretenden *Puccinia*-Arten. (Taf. XII.)

„ 6. KNY: Ein Beitrag zur Kenntniss der Markstrahlen dicotyler Holzgewächse. (Taf. XIII.)

„ — ROTHAM: Zur Kenntniss der Gefässquernetze.

„ — NIEDENZU: Ueber eine neue Eintheilung der Malphighiaceae.

„ 7. WIESNER: Versuch einer Erklärung des Wachsthums der Pflanzenzelle.

„ — REINKE: Uebersicht der bisher bekannten Sphacelariaceen (with 3 woodcuts).

„ — MOELLER: Beitrag zur Kenntniss der *Frankia subtilis*, Brunchorst (with woodcut).

„ 8. MÜLLER, C.: Ueber die Balken in den Holzelementen der Coniferen. (Taf. XIV.)

„ — ZIMMERMANN: Ueber Proteinkrystalloide in den Zellkernen der Phanerogamen. (Vorläufige Mittheilung.)

„ — KARSTEN: Ueber die Mangrovevegetation im malayischen Archipel (Vorläufige Mittheil.) (Taf. XV.)

„ — ZACHARIAS: Ueber Bildung u. Wachsthum der Zellhaut bei *Chara foetida*.

„ — KLEBAHN: Ueber die Formen u. den Wirthswechsel der Blasenroste der Kiefern.

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„ 18. WALTER: Ueber die braunwandigen, sklerotischen Farne, mit besonderer Berücksichtigung Russows.

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„ 21. STENZEL: Blüthenbildungen beim Schneeglöckche und Samenformen bei der Eiche (*Quercus*

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„ 2. WALDSCHMIDT: Zur Bakterienfrage.

„ 3. KRONFELD: Neue Beiträge zur Biologie der P No. 9).

„ 4. KOHL: Anatomisch-physiologische Untersuchun Kieselsäure in der Pflanze.

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„ 12. HABERLANDT: Das reizleitende Gewebesystem de

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Nos. 15 & 16.

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„ — BORNMÜLLER: Zur Flora Ost-Bulgariens.

„ 7. SCHUMANN: Beitrag zur Anatomie des Composite

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„ — KÜNDIG: Ein Pflanzenphysiologischer Demonstrationsapparat.

„ 8. RÖLL: Ueber die Veränderlichkeit der Stengelblätter bei den Torfmoosen (continued in No. 9).

„ 10. BLOCKI: *Rosa cilato-sepala*, n. sp.

„ 12. WILLKOMM: Vegetationsverhältnisse von Traz os Montes (continued in Nos. 13–16).

„ 15. KELLER: Beiträge zur schweizerischen Phanerogamenflora (continued in Nos. 16–19).

„ 17. WARNSTORF: *Sphagnum degenerans*, var. *immersum*, ein neues europäisches Torfmoos.

Nos. 18 & 19.

BÖCKELER: Ueber eine neue *Carex*-Art vom Rigi u. eine zweite wieder aufgefundene Schkur'sche Art von den Süd-Alpen.

No. 20. BÜNGER: Beiträge zur Anatomie der Laubmooskapsel (continued in Nos. 22–25).

„ RÖLL: Ueber die Warnstorf'sche *Acutifolium*-gruppe der europäischen Torfmoose (continued in Nos. 22–25).

„ 24. KRONFELD: Schaftblätter bei *Taraxacum officinale*, Wigg.

„ 26. GELERT: Batologische Notizen.

„ — KORZCHINSKY: Ueber eine hybride *Anemone* Ost-Russlands.

„ — MASSALONGO: Ueber einige neue Micromycetes.

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„ 35. NAWASCHIN: Was sind eigentlich die sogenannten Mikrosporen der Torfmoose?

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„ 42. MIGULA: Beiträge zur Kenntniss des *Gonium pectorale* (continued in Nos. 43 & 44).

„ 46. HELDREICH: Ueber *Campanula anchusiflora* u. *C. tomentosa* der griechischen Flora.

„ 47. LINDMAN: Einige Notizen über *Viscum album*.

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Nos. 3 & 4.

TUBEUF: Ueber das Schmarotzen von Lorantha Aesten (continued in No. 5).

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„ — ———: Die Buchenkeimlinge vom Sommer 188

„ 15. ALLESCHER: Ueber einige aus dem südlichen bekannte Sphaeropsideen u. Melanconiee 16–17).

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„ 20. ———: Ueber die Beschädigung der Coniferen du

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„ 50. HARTIG: Die Waldbeschädigungen durch die No

Botaniska Sektionen af Naturvetenskapliga Studentsallska

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„ 7. STARBÄCK: Zwei am 'Slottsbacken' in Upsala gamen.

„ 8. LUNDSTRÖM: Einige neuere Untersuchungen über

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No. 1. PETRUSCHKY: Die Farbenreaktion bakterieller Stc Lackmus als Beitrag zur Charakteristik Unterscheidung von Bakterienarten (contir

„ — CLAESSEN: Ueber einen indigoblauen Farbstoff aus Wasser.

„ 3. KLEIN: Ein fernerer Beitrag zur Kenntniss des disease.

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No. 3. LUDWIG: Eine neue verheerende Rostkrankheit australischer Akazien, verursacht durch *Uromyces* (*Pileolaria Tepperianus*, Sacc.).

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„ 8. BABES: Vorläufige Mittheilungen über einige bei Influenza gefundene Bakterien (continued in Nos. 15–19).

„ 13. BONOME: Ueber die Unterscheidungsmerkmale zwischen dem *Streptococcus* der epidemischen Cerebrospinal-Meningitis u. dem *Diplococcus pneumoniae.*

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„ 14. KRÜGER: Bakteriologische chemische Untersuchung käsiger Butter (continued in Nos. 15–16).

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„ — LEHMANN: Ueber die pilztödtende Wirkung des frischen Harns des gesunden Menschen.

„ 16. KLEIN: Zur Aetiologie der Diphtherie (continued in No. 17).

„ — SMITH: Das Gährungskölbchen in der Bakteriologie. (Illustrated.)

„ 17. BORDONI-UFFREDUZZI U. GRADENIGO: Ueber die Aetiologie der Otitis media (continued in No. 18).

„ 18. HEIDER: Ueber das Verhalten der Ascosporen von *Aspergillus nidulans*, Eidam, im Thierkörper.

„ 19. KRÜGER: Beitrag zum Vorkommen pyogener Kokken in Milch.

„ — POPOFF: Kann das Kreatin eine nahrhafte Substanz für pathogene Bakterien u. eine Quelle der Bildung von Toxinen sein?

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„ 21. BORDONI-UFFREDUZZI: Neuer *Streptococcus* oder *Diplococcus lanceolatus?*

„ 22. ———————: Ueber die Aetiologie der Otitis media.

„ 23. BUCHNER: Ueber den Färbungswiderstand lebender Pilzzellen.

„ 25. KLEIN: Ein weiterer Beitrag zur Aetiologie der Diphtherie.

Bd. VIII.

No. 1. BUCHNER: Ueber die Ursache der Sporenbildung beim Milzbrandbacillus.

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„ 4. SCHMELCK: Backterioskopische Untersuchungen des Trinkwassers in Christiania. (Illustrated.)

„ 6. BONOME: Ueber die Unterscheidung zwischen *Streptococcus meningitidis* u. *Diplococcus pneumoniae.*

„ — JANOWSKI: Zur Biologie der Typhus-bacillen (continued in Nos. 7–9).

„ 8. SCHEIBE: Bakteriologisches zur Otitis media bei Influenza.

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„ — KÜHNE: Die Untersuchung von Sputum auf Tuberkelbacillen.

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" 14. JANOWSKI: Zur Biologie der Typhusbacillen, II (continued in No. 15).

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" 22. CZAPLEWSKI: Zum Nachweis der Tuberkelbacillen im Sputum (continued in No. 23).

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„ — WITTMACK: *Vriesea* x *Weyringeriana*, n. hyb. (Illust.)

„ — WOLF: *Spiraea Opulifolia*, L., var. *Heterophylla fol. aur. marg.*, Wolf. (Illust.)

„ — ULRICHS: Die gelbe Schnee-Ranunkel der Appenninen.

„ 2. ZABEL: *Philadelphus microphyllus*, Gray. (Illust.)

„ — HAMPEL: Ein neues Gemüse (*Stachys affinis*). (Illust.)

„ 3. REGEL: *Eremurus bucharicus*, Rgl. (Taf. 1314.)

„ — ———: *Odontoglossum cristatum*, Lindl., var. *Lehmanni*. (Taf. 1315.)

„ — ZABEL: *Lonicera splendida*, Boiss. (Illust.)

„ — JÖRNS u. KLAR: Kulturversuche auf den Rieselfeldern zu Blankenburg.

„ — FLECHTNER: Ueber neue u. seltenere Gefässkryptogamen.

„ 4. WITTMACK: *Billbergia Saundersii*, Hort. Bull. (Taf. 1316.)

„ — KOOPMANN: Zum Versuchs-Schnitt am Obstbaum.

„ 5. REGEL: *Allium kansuense* u. *A. cyaneum*. (Taf. 1317.)

„ — LINDBERG: *Rhipsalis Regnellii*, n. sp. (Illust.)

„ 6. WITTMACK: *Billbergia* x *Perringiana*, Wittm. (*B. nutans* x *Liboniana*). (Taf. 1318.)

„ — LINDBERG: *Lepismium* (?) *dissimile*, n. sp. (Illust.)

„ 7. LEDIEN: *Laelia pumila*, Rchb. f., and var. *Dayana*. (Taf. 1319.)

„ — GOETHE: Obstbaubriefe, III.

„ — KRAMER: *Dendrobium Ainsworthii*, *Leechianum*, u. *splendidissimum*. (Illust.)

„ — KOEHNE: *Lonicera Alberti*, Rgl., seit Jahren bekannt.

„ — MATHIEU: Die Spielarten der chinesischen Primel.

„ 8. WITTMACK: *Billbergia Quintusiana*, Hort. Makoy. (Illust.)

„ — BOLLE: Die Eukalyptusweide (*Salix adenophylla*, Hook.).

„ — MÜLLER, R.: *Arundo Donax fol. varieg.* (Illust.)

„ 9. REGEL: *Lycaste Schilleriana*, Rchb. f. *β. Lehmanni*, Rgl. (Taf. 1321.)

„ — HENNINGS: *Encephalartos Hildebrandtii*, A. Br. u. Bouché, eine Form von *E. villosus*, Lehm. (Illust.)

Garden Flora (*continued*).
Heft 9. GILBERT: Die Stubenzucht der Amaryllis.
" " ZABEL: *Cassinia fulvida*, Hook. (Illust.)
" " Das grösste Pflanzenfossil des Kontinents.
" 10. *Streptocarpus* x *controversus*, neue Pflanze.
" 11. WITTMACK: *Nidularium princeps*, var. *magnificum*, Kittel. (Taf. 1323.)
" — ————: *Callistemon lanceolatum*, Sm. (Illust.)
" — ————: *Billbergia vittata*, Brongn., var. *Rohani*. (Illust.)
" 12. SOMMER: *Pescatorea Klabochorum*, Rchb. f. (Taf. 1324.)
" — WITTMACK: *Vriesea Kitteliana* (*V. Barilletii*, E. Morr. x *V. Saundersii*). (Illust.)
" 13. ————: *Rhodostachys pitcairniaefolia*, Benth., var. *Kirchhoffiana*. (Taf. 1325.)
" — HILDEBRAND: Bastarde zwischen *Chamaedorea Schiedeana* u. *C. Ernesti Augusti*. (Illust.)
" 14. KRÄNZLIN: *Odontoglossum Andersonianum*, fl. dupl. (Taf. 1326.)
" — HENNINGS: Ueber *Abies Eichleri*, Lauche = *A. Veitchii*, Lindl. (Illust.)
" 15. ILLAIRE U. WITTMACK: *Iris Danfordiae*, Baker. (Taf. 1327.)
" — BIEDERMANN: *Lopezia racemosa*. (Illust.)
" — MÖHL: Rinden- u. Wurzelbildung im Innern eines Lindenstammes.
" 16. REGEL: *Miltonia flavescens*, Lindl., var. *grandiflora*. (Taf. 1328.)
" — BOLLE: Wann erscheint die Weymouthskiefer zuerst in Europa?
" 17. SOMMER: *Masdevallia Shuttleworthii*, Rchb. f. (Taf. 1329.)
" — MATHSSON: Reisebericht eines Cacteensammlers in Mexiko (continued in No. 18).
" — WITTMACK: *Odontoglossum Insleayi*, Lindl.
" 18. REGEL: *Asparagus Sprengeri*, Rgl. (Illust.)
" — HENNINGS: Ueber *Isaria rhodosperma*, Bres., n. sp., an Stämmen von *Seaforthia elegans*.
" — WITTMACK: *Vriesea Gravisiana*, n. sp. (Illust.)
" 19. ————: *Echino-cereus pectinatus*, var. *robustus*. (Taf. 1331.)
" 20. STEIN: *Vanda coerulea*, Griff. (Taf. 1332.)
" — SCHARRER: Nochmals *Abies Eichleri*.
" 21. REGEL: *Maxillaria Mülleri*, n. sp.
" 22. WITTMACK: *Lotus peliorhynchus*, Webb., eine neue Ampelpflanze. (Taf. 1334.)
" — REGEL: *Saccolabium bivittatum*, n. sp.
" — STEIN: Ein neuer Insektenfänger.
" 23. KRÄNZLIN: *Stanhopea Spindleriana*, n. hyb. (Taf. 1335.)

Hedwigia. Bd. XXIX.

Heft 1. STEPHANI: Die Gattung *Lejeunea* im Herbarium Lindenberg (continued in Heft 2, 3).
" — MAGNUS: Bemerkung über die Benennung zweier auf *Alnus* lebender *Taphrina*-Arten.
" — DIETEL: Beschreibung eines neuen Phragmidiums.
" — KLEBAHN: Neue Untersuchungen u. Beobachtungen über die Blasenroste der Kiefern.
" — KLEIN: Ueber den Formenkreis der Gattung *Volvox* u. seine Abhängigkeit von äusseren Ursachen.

Hedwigia (*continued*).

Heft 2. SCHRÖTER: Pilze Serbiens, I.
„ — MAGNUS: Die systematische Stellung von *Hydnocystis*, Jul.
„ — ELLIOTT: Ueber einige in Madagascar gefundene Pilze.
„ — WARNSTORF: Nachträgliche Notiz zu: Ueber das Verhältniss zwischen *Sph. imbricatum*, Hornsch., *Sph. Portoricense*, Hpe., and *Sph. Herminieri*, Schpr. in Hedw. 1889, p. 303.
„ 3. LAGERHEIM: *Harpochytrium* u. *Achlyella*, zwei neue Chytridiaceengattungen. (Taf. II.)
„ — MAGNUS: Ein bemerkenswerthes Auftreten des Hausschwammes *Merulius lacrimans*, (Wulf.) Schum. im Freien.
„ — KARSTEN: Fragmenta mycologica, XXIX.
„ — DIETEL: Ueber den Generationswechsel von *Uromyces lineolatus*, (Desm.) Schröt.
„ — ———: Beschreibung der Teleutosporenform von *Uredo agrimoniae*, DC.
„ — SACCARDO: Fungi aliquot australienses.
„ 4. FISCHER: Beiträge zur Kenntniss exotischer Pilze.
„ — LAGERHEIM: *Puccinia singularis*, Magnus, and *P. Bäumleri*, Lagerheim.
„ — KARSTEN: Fragmenta mycologica, XXX.
„ — WARNSTORF: Beiträge zur Kenntniss exotischer Sphagna (continued in Heft 5).
„ 5. DIETEL: Uredineen aus dem Himalaya.
„ — KARSTEN: Fragmenta Mycologica, XXXI.
„ — STOCKMAYER: *Vaucheria caespitosa*. (Taf. XVI.)

Helios. (Berlin, 1890.) Jahrg. VIII.

No. 2. *Populus Viadri*, n. sp.
„ 3. HUTH: Weitere Bemerkungen über Schleuderfrüchte.
„ 8. Die Ursache der sog. 'Hexenbesen.'

Abhandlungen.

HUTH: Systematische Uebersicht der Schleuderfrüchte.
MÜLLER: Der mikroskopische Aufbau der Pflanzenblätter.
HUTH: Revision der Arten von *Adonis* u. *Knowltonia*.
———: Ueber geokarpe, amphikarpe u. heterocarpe Pflanzen.
ZACHARIAS: Die Bedeutung der Schneedecke für die Pflanzenwelt.

Jahrbuch der Kön. Preussischen Geologischen Landesanstalt u. Bergakademie zu Berlin, 1888. (Berlin, 1889.)

WEISS: Fragliche *Lepidodendron*-reste im Rothliegenden und jüngeren Schichten. (m. Taf.)

Jahrbücher, Engler's Botanische. (Leipzig.)

Bd. XI (*continued*).

Heft 4. IVANITZKY: Verzeichniss der im Gouvernement Wologda wildwachsenden Pflanzen.
„ — REINSCH: Ueber die anatomischen Verhältnisse der Hamamelidaceae mit Rücksicht auf ihre systematische Gruppierung. (Taf. VIII.)
„ — KUHN, HACKEL, BÖCKELER, U. BUCHENAU: Plantae Marlothianae, Nachtrag: *Polypodiaceae*, *Gramineae*, *Cyperaceae*, u. *Juncaceae*.
„ — GARCKE: Ueber *Cassine domingensis*, Spr.
„ — IANKÓ: Abstammung der Platanen. (Taf. IX u. X.)

Jahrbücher, Heft 5.

Engler's Botanische (*continued*).

RICHTER: Zwei für die Flora von Ungarn neue Soldanellen: *S. minima*, Hoppe, u. *S. pusilla*, Baumg. × *S. montana*, W., hybr. nov. (With Woodcut.)

" — GARCKE: Was ist aus *Astropus tomentosus*, Spr. geworden?

" — ENGLER: Eine neue Burseracea und zwei neue Anacardiaceae aus West Afrika.

Bd. XII.

Heft 1, 2. BUCHENAU: Monographia Juncacearum (continued in Heft 3 and 4). (Taf. I, II.)

" — TAUBERT: Plantae Glaziovianae novae vel minus cognitae. (Taf. I A.)

" — KLATT: Compositae Hildebrandtianae in Madagascaria centrali collectae.

" — GARCKE: Ueber einige Arten von *Melochia*.

" 3, 4. ENGLER: Beiträge zur Kenntniss der Sapotaceae. (With Woodcut.)

" — SCHWACKE: Eine brasilianische *Gunnera* (*G. manicata*, Linden). (With Woodcut.)

" — ————: Ein Ausflug nach der Serra da Caparao (Staat Minas, Brasilien) nebst dem Versuche einer Vegetationsskizze der dortigen Flora.

" — TAUBERT: Die Gattung *Otacanthus*, Lindl. u. ihr Verhältniss zu *Tetraplacus*, Radlk.

Bd. XIII.

Heft 1. RACIBORSKI: Ueber die Osmundaceen u. Schizaeaceen der Juraformation. (Taf. I.)

" — CHRIST: *Euphorbia Berthelotii*, Bolle.

" — SIMON: Beiträge zur vergleichenden Anatomie der Epacridaceae u. Ericaceae. (Taf. II.)

" — BRIQUET: Recherches sur la Flore du district savoisien et du district jurassique franco-suisse avec aperçus sur les Alpes occidentales en général. (Tab. III et IV.)

" — LINDAU: Monographia generis Coccolobae (continued in Heft 2).

" 2. WARBURG: Beiträge zur Kenntnis der papuanischen Flora.

Jahrbücher für wissenschaftliche Botanik—Pringsheim. (Berlin.)

Bd. XXI (*continued*).

Heft 3. WENT: Die Entstehung der Vacuolen in den Fortpflanzungszellen der Algen. (Taf. XI und XII.)

" — KOCH: Die Paraffineinbettung u. ihre Verwendung in der Pflanzenanatomie.

" — BOKORNY: Die Wege des Transpirationsstromes in der Pflanze.

" 4. ————: Weitere Mittheilung über die wasserleitenden Gewebe.

" — KRABBE: Untersuchungen über das Diastaseferment unter specieller Berücksichtigung seiner Wirkung auf Stärkekörner innerhalb der Pflanze. (Taf. XIII–XV.)

" — NADELMANN: Ueber die Schleimendosperme der Leguminosen. (Taf. XVI–XVIII.)

Bd. XXII.

Heft 1. KOCH: Zur Entwickelungsgeschichte der Rhinanthaceen (II, *Euphrasia officinalis*, L.). (Taf. I.)

" — DE VRIES: Ueber abnormale Entstehung secundärer Gewebe. (Taf. II und III.)

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Heft 1. FISCHER: Beiträge zur Physiologie der Holzgewächse.

„ 2. CORRENS: Beiträge zur biologischen Anatomie der Aristolochia-Blüthe. (Taf. IV und V.)

„ — ————: Zur Biologie u. Anatomie der Salvien-blüthe. (Taf. VI und VII.)

„ — ————: „ „ Calceolarien-blüthe. (Taf. VIII.)

„ — BLASS: Untersuchungen über die physiologische Bedeutung des Siebtheils der Gefässbündel. (Taf. IX und X.)

„ 3. EBERDT: Beiträge zur Entstehungsgeschichte der Stärke. (Taf. XI und XII.)

„ — BREDOW: Beiträge zur Kenntniss der Chromatophoren.

„ — KLEBAHN: Studien über Zygoten, I. Die Keimung von *Closterium* u. *Cosmarium*. (Taf. XIII und XIV.)

Jahresbericht der Schlesischen Gesellschaft für vaterländische Cultur. (Breslau, 1890.) Bd. LXVII.

ROSENFELD: Ein neuer *Bacillus* in Kommaform. p. 41.

AHRENS: Resultate der chemischen Untersuchung der Wurzel der *Mandragora officinalis*, Mill. p. 113.

COHN: Ueber Aposporie bei *Athyrium Filix foemina*, var. *clarissimum*. p. 151.

EIDAM: Ueber neue botanische Modelle. p. 158.

ENGLER: Ueber die Familie der Loranthaceen. p. 147.

FICK: Resultate der Durchforschung der schlesischen Phanerogamenflora im Jahre 1889. p. 161.

PAX: Ueber das Variiren der Blätter u. Früchte in der Gattung *Acer*. p. 153.

——: Ueber Wurzeln von *Anthriscus nitida* mit Adventivknospen. p. 152.

SCHUBE: Ueber die botanischen Ergebnisse seiner Reise nach Norwegen. p. 160.

————: Ueber Verbänderungen, beobachtet an schlesischen Pflanzen im Jahre 1888. p. 152.

STENZEL: Fruchtformen des Bergahorns. p. 150.

————: Ueber gefüllte Blüthen von *Cyclamen*. p. 159.

————: Verwachsene Früchte von *Tragopogon pratensis*. p. 151.

WERNER: Ueber Oleum Betel u. Oleum Macassar. p. 153.

Jahresbericht des Vereins für Naturkunde zu Zwickau in Sachsen. (Zwickau, 1890.) 1889.

SCHLECHTENDAL: Teratologische Aufzeichnungen. (Taf. I und II.)

WÜNSCHE: Beiträge zur Flora von Sachsen.

Jahresbericht u. Abhandlungen des Naturwissenschaftlichen Vereins in Magdeburg. (Magdeburg, 1890.)

1889. EBELING: Kätzchenträger, Amentaceen.

————: Die Ambrosiaceen (Compositae).

————: Die Familie der Resedagewächse (Resedaceen).

Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg. (Stuttgart, 1890.) Jahrg. XLVI.

HEGELMAIER: Ueber einen Fall von abnormer Keimentwickelung. (Taf. I.)

————: Zur Kenntniss der Formen von *Spergula*, L. mit Rücksicht auf das einheimische Vorkommen derselben.

RIEBER: Beitrag zur Flora von Württemberg u. Hohenzollern.

Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg (*continued*).

SCHEIFFELE: Volkstümliche Pflanzennamen aus dem Gebiet der Rauhen Alp.

ENGEL: Palæontologische Funde aus dem Lias und des Filsbetts bei Eislingen.

Mittheilungen aus dem Kön. Mineralogisch-geologischen u. Prähistorischen Museum in Dresden. (Cassel, 1890.) Heft 9.

GEINITZ: Ueber einige Lycopodiaceen aus der Steinkohlenformation.

Mittheilungen der Geographischen Gesellschaft zu Jena, zugleich Organ des Botanischen Vereins für Gesamtthüringen. Jena, 1890.

Bd. VIII (*continued*). Heft 3 u. 4.

DIETEL: Ueber die Gattung *Pileolaria*, Cast. (m. Taf.)

BLIEDNER: Verzeichnis in der Flora von Eisenach neuerdings wieder nachgewiesener oder zum ersten Male beobachteter Pflanzen.

HAUSSKNECHT: Kleinere botanische Mitteilungen. (Chiefly new records for neighbouring flora.)

SCHULZE: *Thymus celakovskyanus.*

APPEL: Caricologische Notizen aus dem herzynischen Gebiet.

TORGES: Ueber Potentillakulturen u. Exsiccaten des Herrn Siegfried.

Bd. IX. Heft 1 u. 2.

APPEL: Beiträge zur Kenntnis der Gattung *Carex.*

———: *Calamagrostis arundinacea* × *villosa*, n. hyb. *C. indagata*, Torges u. Hskn.

Mittheilungen des Badischen Botanischen Vereins. (Freiburg, 1890.) Nos. 75–80.

KNEUCKER: *Inula hirta* × *salicina* (*I. rigida*, Döll.).

———: *Inula brittanica*, L., var. *Oetelliana*, Rchb.

SCHATZ: *Salix caprea* × *purpurea.*

WINTER: Flora von Achern.

ZAHN: Altes u. Neues aus der badischen Flora.

HILDEBRAND: *Campanula rhomboidalis*, A. in der Flora von Freiburg.

RÄUBER: Eine Pfingstexcursion an den Kaiserstuhl.

Mittheilungen, Mathematische u. Naturwissenschaftliche, aus den Sitzungsberichten der K. Preussischen Akad. der Wissenshaften zu Berlin. 1890. (Berlin, 1890.)

Heft 2. TSCHIRCH: Die Saugorgane der Scitamineen-Samen.

„ 3. STRASBURGER: Die Vertreterinnen der Geleitzellen im Siebtheile der Gymnospermen. (Taf. I.)

„ 4. SCHWENDENER: Die Mestomscheiden der Gramineenblätter. (Taf. II.)

„ 7. SCHIMPER: Ueber Schutzmittel des Laubes gegen Transpiration, besonders in der Flora Java's.

Mittheilung, Monatliche, des Naturw. Vereins, Frankfurt a. d. Oder.

Bd. VII (*continued*), Nos. 11 u. 12.

HÖCK: Heimath der angebauten Gemüse.

Bd. VIII, Nos. 1–6.

HUTH: Systematische Uebersicht der Schleuderfrüchte.

——: Revision der Arten von *Adonis* u. *Knowltonia.*

———: Ueber geokarpe, amphikarpe u. heterokarpe Pflanzen.

MÜLLER: Der mikroskopische Aufbau der Pflanzenblätter.

Mittheilungen, Petermanns. (Gotha, 1889–90.)

Bd. XXXV (*continued*).

No. 12. DRUDE: Betrachtungen über die hypothetischen vegetationslosen Einöden im temperierten Klima der nördlichen Hemisphäre zur Eiszeit.

Bd. XXXVI.

No. 12. RATZEL: Versuch einer Zusammenfassung der wissenschaftlichen Ergebnisse der Stanleyschen Durchquerung—Das Waldland Inner Afrikas.

Ergänzungsheft.

No. 95. PARTSCH: Die Insel Leukas—Natur u. Kultur. p. 22.

„ 97. DOVE: Kulturzonen von Nord-Abessinien.

Monatsschrift, Deutsche Botanische. Jahrgang VIII.

No. 1. BURCHARD: Herbstudien eines Bryologen (im Schwarzwald) (continued in Nos. 3, 4).

„ — SABRANSKY: Batographische Miscellaneen, II. Zur Flora des bayerischen Böhmerwaldes.

„ — GEISENHEYNER: Ein bigenerischer Bastard (*Anthemis tinctoria* × *Matricaria inodora*).

„ 2. STRÄHLER: Ueber *Pulsatilla vernalis, patens*, u. *pratensis*.

„ — GLAAB: Beobachtungen über die Entwicklung des Blüten- u. Fruchtstandes von *Trifolium subterraneum*, L.

„ — ERCK: Ueber die Capreaceen u. deren Bastarde (continued in Nos. 9, 10).

„ — LUDWIG: Nachträge zur Flora von Ida-Waldhaus bei Greiz.

„ — KESSLER: Der Staffelberg in Oberfranken (continued in Nos. 5, 6).

„ — STRÄHLER: Salicologisches.

„ — KÖNIG: Zur Flora von Kassel (continued in Nos. 5, 6).

„ 3, 4. WEISS: Die Bayerische botanische Gesellschaft zur Erforschung der heimischen Flora u. ihre Organisation.

„ — GRÜTTER: Noch Einiges über unsere Pulsatillen u. deren Bastarde.

„ — ROTTENBACH: Seltene Farne Thüringens.

„ — Beiträge zur Flora des Regnitzgebietes (*continued*).

„ — KNEUCKER: Botan. Wanderungen im Berner Oberland u. im Wallis (continued in Nos. 9, 10).

„ — SCHAMBACH: Zusätze u. Bemerkungen zu Garckes Flora von Deutschland.

„ — PETZOLD: Volkstümliche Pflanzennamen aus dem Nördlichen Teile von Braunschweig (continued in Nos. 5–10).

„ — FIGERT: *Typha latifolia* × *angustifolia*.

„ 5, 6. FORMÁNEK: Beitrag zur Flora von Serbien, Macedonien u. Thessalien.

„ — FREYN: Ranunculaceae aus dem westlichen Nord-Amerika (continued in Nos. 11, 12).

„ — GRÜTTER: *Lepidium micranthum*, Led.

„ — FIGERT: *Salix pulchra*, Wimm.

„ — GEISENHAYNER: *Lycium rhombifolium*, Dippel.

„ — LUDWIG: Ueber Verbreiter der Alkoholgärung der Eichen.

„ 7, 8. MAGNUS: Eine weisse *Neottia nidus-avis*.

„ — FICK: Ueber neue Erwerbungen der schlesischen Flora.

„ — BRUHNI: Die linicolen u. Luzerne-Unkräuter Deutschlands u. der Schweiz.

„ — APPEL: Coburgs Cyperaceen.

„ — KÜKENTHAL: *Carex glauca* × *tomentosa*, n. hyb.

Monatsschrift, Deutsche Botanische
No. 7, 8.

Deutsche Botanische (*continued*).

MURR: Beiträge zur Kenntniss der Hieracien Nordtirols.

ZAHN: Berichtigungen u. Ergänzungen zur 16. Aufl. von Garckes Flora v. Deutschland.

„ — GELMI: Ueber *Rosa canina* u. *R. glauca* der tridentinischen Alpen.

„ — KNUTH: Sommerwanderungen auf Sylt.

„ — WINKLER: Ueber *Lepidium micranthum*, Ledeb.

„ — WINTER: *Hypnum flagellare*, Dicks. zum ersten Male frukt. in Deutschland.

„ — GLAAB: Ueber *Amorphallus Rivieri*, Dur.

„ 9, 10. SAGORSKI: Ueber den Formenkreis der *Anthyllis vulneraria*, L. nebst einigen Betrachtungen über polymorphe Arten.

„ — ERCK: Beobachtungen.

„ — ZAHN: *Cirsium oleraceum* × *arvense* (*C. Reichenbachianum*, Lohr. f.).

„ — ROLL: Die Laubmoose Thüringens u. ihre geographische Verbreitung.

„ — MEIGEN: Zwei Pelorien v. *Galiopsis Tetrahit*, L.

„ 11, 12. FORMÁNEK: Beitrag zur Flora von Serbien, Macedonien u. Thessalien.

„ — KNEUCKER: Botanische Wanderungen im Berner Oberland u. Wallis.

„ — PETZOLD: Volksthümliche Pflanzennamen.

„ — v. HOLLE: Beobachtungen betr. *Hieracium praecox*, II, *basalticum*, C. H. Schultz.

Schriften der Naturforschenden Gesellschaft in Danzig. (Danzig, 1890.) Bd. VII. Heft 3.

CONWENTZ: Alte Bäume in Kreise Elbing.

KLINGGRÄFT: Schmetterlingsfang der *Drosera anglica*, Huds.

LAKOWITZ: *Betuloxylon Geinitzii*, n. sp., u. die fossilen Birkenhölzer. (Taf. I.)

LUDWIG: Die konstanten Strahlenkurven der Kompositen u. ihre Maxima.

———: Weitere Beobachtungen von Fritz Müller über das Variiren der Blütenzahl von *Hypoxis decumbens*.

Schriften der Physikalisch-Ökonomischen Gesellschaft zu Königsberg in Pr. (Königsberg, 1890.) Jahrg. XXX (1889).

SCHARLOK: Mitteilungen über bemerkenswerte Pflanzen der Graudenzer Umgegend, nebst Ergebnissen mehrjähriger Beobachtung an cultivirten Exemplaren.

FRÖLICH: Ueber seine Exkursionen in den Kreisen Pr. Stargard, Berent, u. Konitz.

GRÜTTER: Ueber seine Exkursionen im Jahre 1888.

Für das Gebiet neuer Pflanzen—Systematische Zusammenstellung der wichtigeren Funde von neuen Standorten.

Schriften des Naturwissenschaftlichen Vereins des Harzes. (Wernigerode, 1889.) Bd. IV.

WARNSTORF: *Riccia Hübeneriana*, Lindenberg, in der Mark aufgefunden.

FORCKE: Nachträge zu Sporleder's Verzeichniss der in der Grafschaft Wernigerode u. nächster Umgegend wildwachsenden Phanerogamen u. Gefäss-Cryptogamen.

Sitzungsberichte der Gesellschaft für Morphologie und Physiologie zu München. (Münich, 1889.) Bd. V (*continued*).

Heft 2. BUCHNER: Ueber die bacterientödtende Wirkung des zellenfreien Blutserums.

„ — LOEW: Ueber den Eiweissumsatz in den Pflanzen.

Sitzungsberichte der Gesellschaft für Morphologie und Physiologie zu München (*continued*).

Bd. VI.

Heft 1. HARTIG: Ueber die Folgen der Baumringelung.

Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin. (Berlin, 1890.) Jahrg. 1890.

ASCHERSON: Fundorte von *Lasiospermum brachyglossum*, var. *sinaicum* u. *Convolvulus Schimperi*. p. 57.

——— : Das Vorkommen der *Scopolia carniolica* in Ostpreussen. pp. 49 u. 81.

JÄKEL: Gänge von Fadenpilzen (*Mycelites ossifragus*) in Dentinbildungen. p. 92.

MAGNUS: Eine neue *Puccinia* auf *Anemone ranunculoides*. p. 29.

———: Eine interessante Phalloidee, *Kalchbrennera corallocephala*. p. 44.

———: Merkwürdige Hyacinthe. p. 45.

———: Epidemische Erkrankung der Nelken. p. 47.

———: Das Vorkommen der *Puccinia singularis*, Magn. p. 145.

MÜLLER: Vorkommen freier Gefässbündel in den Blattstielen kräftiger Umbelliferen, sowie Compositen. p. 131.

ZUELZER: Wurzeln der *Mandragora officinalis*. p. 142.

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Heft 1 u. 2, 1890.

RADLKOFER: Ueber die Gliederung der Familie der Sapindaceen.

Sitzungsberichte der Physikalisch-medicinischen Gesellschaft zu Würzburg.

Jahrg. 1889 (*continued*).

No. 10. SANDBERGER: Bemerkungen über die fossile Flora des Infralias-Sandsteins von Burgpreppach bei Hassfurt. p. 158.

Jahrg. 1890.

No. 3. LEHMANN: Ueber einige Bedingungen der Sporenbildung beim Milzbrand.

Sitzungsberichte der Physikalisch-medicinischen Societät in Erlangen. (Munich, 1890.) Heft 21 (1889).

SCHULZ: Untersuchungen über den Einfluss der Mikroorganismen auf die Oxydationsvorgänge im Erdboden.

BOKORNY: Ueber die Wasserwege in den Pflanzen.

——— : Ueber Aggregation.

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Jahrg. 1889, Juli bis December.

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DRUDE: Durchforschung der Torfmoose mit Rücksicht auf Pflanzengeographie.

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DRUDE: Die Forschungsresultata der Plankton-Expedition.

——— : Die Schwierigkeit exacter Bestimmungen tertiärer Proteaceen.

——— u. VETTER: Moritz Wagner's Wirken u. Schaffen.

Abhandlungen.

ENGELHARDT: Chilenische Tertiärpflanzen.

Tweedehalf der Heidelberg. CONWENTZ

62. Versammlung Deutscher Naturforscher u. Ärzte. (Heidelberg, 1890.)

CONWENTZ: Ueber zweierlei Thyllenbildung im Holze der Bernsteinbäume. p. 253.

KLEIN: Ueber Entwickelung u. Vertheilung der reproductiven Individuen in den *Volvox*-colonien. p. 253.

———: Ueber Sporenbildung u. Sporenkeimung bei den endosporen Bacterien.

ZACHARIAS: Ueber die Zellen der Cyanophyceen.

KRONFELD: Ueber vergrünte Blüthen von *Typha minima*.

TSCHIRCH: Keimungsversuche.

———: Ob das Licht zu den unmittelbaren Lebensbedingungen der Pflanzen oder einzelner Pflanzenorgane gehört.

FRANK: Die Pilzsymbiose der Leguminosen.

ASKENASY: Ueber Beziehungen zwischen Temperatur u. Wachsthum.

KRONFELD: Ueber die künstliche Besiedelung einer Pflanze mit Ameisen.

Verhandlungen des Botanischen Vereins der Provinz Brandenburg. (Berlin, 1889–90.) Jahrg. XXXI.

Verhandlungen.

LUDWIG: Der Farbstoff der *Synchytrium*-gallen von *Anemone nemorosa*.

HENNINGS: Ueber *Isaria rhodosperma*, Bres., n. sp., an Stämmen von *Seaforthia elegans* im Berliner Botanischen Garten.

BEYER: Ein neuer *Achillea*-Bastard.

ASCHERSON: Ueber das Vorkommon eines Rudiments des hinteren unpaaren Staubblattes bei *Gratiola officinalis*, L. (Woodcut.)

MAGNUS: *Urocystis Kmetiana*, P. Magn., n. sp., im Fruchtknoten von *Viola tricolor arvensis*.

———: Verzeichniss der am 15. u. 16. Juni, 1889, bei Tangermünde beobachteten Pilze.

SCHWEINFURTH: Vorlage von in Spiritus conservirten u. dann getrockneten succulenten u. brüchigen Pflanzen Süd-Arabiens.

MAGNUS: Ein monströses *Acanthus*-Blatt.

———: Eine Sammlung von Blättern bei Potsdam cultivirter Holzgewächse.

———: Bemerkenswerte Blitzschläge. (With 5 Woodcuts.)

JACOBASCH: Blitzschlag in vier Bäume der Jungfernheide.

WINKELMANN: Vorlage von Pflanzen aus der Stettiner Flora.

LEHMANN: *Pinus Mughus* im October männliche Blüten entwickelnd.

Abhandlungen.

LOEW: Beiträge zur blütenbiologischen Statistik.

———: Liste der Insektenbesuche an Blumen.

BÜTTNER: Neue Arten von Guinea, dem Kongo u. Quango.

WINKLER: *Conioselinum tataricum*, Fischer, u. *Acanthus longifolius*, Host. in ihrem Jugendzustande. (Taf. I, II.)

WARNSTORF: *Bartramia Halleriana*, Hedw., ein für die Mark neues Laubmoos.

THOMAS: Ueber das Heteropterocecidium, von *Teucrium capitatum* u. anderen *Teucrium*-Arten.

FOCKE: Der Farbenwechsel der Rosskastanien-Blumen.

SCHUMANN: Einige weitere Ameisenpflanzen.

BOLLE: Unter den Linden des Werbellin. Eine Märkische Studie.

Verhandlungen des Botanischen Vereins der Provinz Brandenburg (*continued*).

MAGNUS: *Thorea ramosissima*, Bory, bei Belgrad in Serbien u. ihre weitere Verbreitung.

POTONIÉ: Das zu *Tylodendron* gehörige Holz u. Laub. (6 Woodcuts.)

HENNINGS: Die in der Umgebung Berlins bisher beobachteten Hymenomyceten, I. Agaricineae.

SCHINZ: Beiträge zur Kenntniss der Flora von Deutsch-Südwest Afrika u. der angrenzenden Gebiete, IV. (Taf. III.)

BUCHENAU: Ueber eine trügerische Form von *Juncus effusus*, L.

RUTHE: Beobachtungen aus der Gefässpflanzenflora des Kreises Usedom-Wollin.

ASCHERSON U. SPRIBILLE: Zwei Neuigkeiten für die Flora der Provinz Posen.

JACOBASCH: Mitteilungen—Verschiedene Blütezeit der rot-, blau- u. weissblütigen Form v. *Hepatica triloba*, Gil.

" Eine Pilzexkursion durch die 'Märkische Schweiz.'

Jahrg. XXXII. Heft 1.

TAUBERT: Monographie der Gattung *Stylosanthes*.

BÜTTNER: Neue Arten von Guinea, dem Congo u. dem Quango, II.

SANIO: Zahlenverhältnisse der Flora Preussens, II. Phanerogamen.

Verhandlungen der Gesellschaft Deutscher Naturforscher u. Ärzte. 63. Versammlung zu Bremen. (Leipzig, 1890.)

Theil 1. WARBURG: Die Flora des asiatischen Monsungebietes.

Verhandlungen der Physikalisch-Medicinischen Gesellschaft zu Würzburg. (Würzburg, 1890.) Bd. XXIII (*continued*).

No. 7. SANDBERGER: Uebersicht der Versteinerungen der Triasformation Unterfrankens.

Verhandlungen des Kaiserl. Leop.-Carol. Deutsch. Academie d. Naturforsch. Halle. (Halle.) Bd. LII und LIII.

WETTERWALD: Blatt- u. Sprossbildung bei Euphorbien u. Cacteen.

KÖPPEN: Verhalten d. Rinde unserer Laubbäume während der Thätigkeit des Verdickungsringes.

WILLE: Entw.-Geschichte der physiologischen Gewebesysteme bei einigen Florideen.

Verhandlungen des Naturforschenden Vereins in Brünn. Bd. XXVII. Jahrg. 1888.

1889. ZOEBL: Der anatomische Bau der Fruchtschale der Gerste.

Verhandlungen des Naturhistorischen Vereines der Preussischen Rheinlande. (Bonn, 1889.) Jahrg. XLVI.

Verhandlungen.

SCHEMMANN: Beiträge zur Phanerogamen- u. Gefässkryptogamen-Flora Westfalens. p. 17.

HACKENBERG: Beiträge zur Kenntniss einer assimilirenden Schmarotzerpflanze (*Cassytha americana*). p. 98. (Illust.)

Korrespondenzblatt.

HUNDHAUSEN: Proben des Pflanzen-Eiweisses 'Aleuronat.' p. 44.

KÖRNICKE: Ueber das Saccharum der Alten. p. 61.

Verhandlungen des Naturhistorischen Vereines der Preussischen Rheinlande (*continued*,).

Sitzungsberichte der Niederrheinischen Gesellschaft.

KÖRNICKE: Ueber die wilden Stammformen unserer Kulturweizen. p. 21.

REIN: Beobachtungen aus dem botanischen Garten zu Valencia. p. 29.

POHLIG: Vorkommen u. Verbreiten der Coniferen in Mexiko. p. 35.

REIN: *Ranunculus bullatus*: Alterthümer von Mérida. pp. 37, 38.

——: Ueber *Garcinia mangostana*. p. 38.

BRANDIS: Specifische Individualität in dem Eintritt u. der Dauer der Blüthezeit der Pflanzen. p. 38.

Zeitschrift für Hygiene. Herausgegeben von R. Koch u. C. Flügge. (Leipzig, 1889–90.)

Bd. VII.

Heft 3. PFEIFFER: Ueber den *Vibrio Metschnikoff* u. sein Verhältniss zur Cholera asiatica (m. Tfl.).

„ — MÖLLER: Erwiderung auf die Abhandlung: 'Die Durchlässigkeit der Luftfiltertuche für Pilzsporen u. Bacterienstäubchen von R. J. Petri.'

„ — KITASATO: Die negative Indolreaction der Typhusbacillen im Gegensatz zu anderen ähnlichen Bacillenarten, etc.

Bd. VIII.

Heft 1. KITASATO: Ueber das Wachsthum des Rauschbrandbacillus in festen Nährsubstraten. (m. Taf.)

„ — HOLZ: Experimentelle Untersuchungen über den Nachweis der Typhusbacillen.

„ 2. ALMQUIST: Untersuchungen über einige Bacteriengattungen mit Mycelien. (m. Taf.)

„ — KITASATO: Untersuchungen über die Sporenbildung der Milzbrandbacillen in verschiedenen Bodentiefen.

„ 3. ——— u. WEIL: Zur Kenntniss der Anaëroben.

„ — BECK: Bacteriologische Untersuchungen über die Aetiologie der menschlichen Diphtherie.

„ — KIRCHNER: Ueber die Einwirkung des Chloroforms auf Bacterien.

„ — NIKOFOROFF: Beitrag zu den Culturmethoden der Anaëroben.

„ — ———: Ueber einen dem *Pneumococcus* sehr ähnlichen Mikroorganismus.

„ — BLÜCHER: Eine Methode zur Plattenculture anaërober Bacterien.

Bd. IX.

Heft 1. KITASATO u. WEIL: Zur Kenntniss der Anaëroben.

„ — FROSCH: Ein Beitrag zur Kenntniss der Ursache der amerikanischen Schweineseuche u. ihrer Beziehung zu den bakteriologisch verwandten Processen.

„ — TILZ: Bacteriologische Untersuchungen der Freiburger Leitungswässer (m. Tfl.).

„ — BABES: Ueber Variabilität u. Varietäten des Typhusbacillus. (m. Tfl.).

„ — BOTKIN: Eine einfache Methode zur Isolirung anaërober Bacterien.

Zeitschrift für Naturwissenschaften. (Halle a. S. 1889–90.) (4. Folge, Bd. VIII.)

Bd. LXII (*continued*).

Originalaufsätze.

Heft 5. PFEIFFER: Ueber Identität des *Boletus Satanas*, Lenz.

Zeitschrift für Naturwissenschaften (*continued*).

Heft 5. SCHLECHTENDAL: Bemerkungen u. Beiträge zu den Braunkohlenfloren von Rott am Siebengebirge u. Schlössnitz in Schlesien. (Taf. II, III.)

Berichte.

Heft 5. HEYER: Wärmeverhältnisse in Baumstämmen.

„ 6. NATHUSIUS: Symbiose der Waldbäume mit *Mykorrhiza*.

„ — SCHENCK: Symbiose einer Ericacee u. *Mykorrhiza*.

Bd. LXIII.

Heft 4, 5. SCHMIDT: Die Einwirkung des Blitzschlages auf verschiedene Baumarten.

„ 6. KÖNIG: Beiträge zur Kenntniss der Alkaloide aus den Wurzeln von *Sanguinaria Canadensis* und *Chelidonium majus*.

Zeitschrift für wissenschaftliche Mikroskopie. (Braunschweig, 1890.)

Bd. VII.

Heft 1. ZIMMERMANN: Botanische Tinctionsmethoden.

„ — OVERTON: Mikrotechnische Mittheilungen aus dem botanischen Laboratorium der Universität Zürich.

„ 2. MIGULA: Methode zur Conservirung niederer Organismen in mikroskopischen Präparaten.

Zeitschrift, Jenaische für Naturwissenschaft. (Jena.) (1889–90.) Bd. XXIV.

Heft 1. BÜSGEN: Beobachtungen über das Verhalten des Gerbstoffes in den Pflanzen.

Bd XXV.

HAECKEL: Plankton-Studien.

Zeitung, Botanische. Jahrg. XLVIII.

No. 1. ZACHARIAS: Ueber die Zellen der Cyanophyceen (continued in Nos. 2–5). (Taf. I.)

„ 6. BEHRENS: Zur Kenntniss einiger Wachsthums- u. Gestaltungsvorgänge in der vegetabilischen Zelle (continued in Nos. 7–10).

„ — HOFFMANN: Ueber phaenologische Accommodation (continued in Nos. 7–11).

„ 7. STANGE: Ueber chemotactische Reizbewegungen (continued in Nos. 8–11).

„ 12. SOLMS-LAUBACH: Die Sprossfolge der *Stangeria* u. der übrigen Cycadeen (continued in Nos. 13–15). (Taf. II.)

„ 16. SORAUER: Mittheilungen aus dem Gebiete der Phytopathologie.

„ 17. JOST: Die Erneuerungsweise von *Corydalis solida*, Sm. (continued in Nos. 18, 19). (Taf. III.)

„ 20. HILDEBRAND: Einige Beiträge zur Pflanzenteratologie (continued in No. 21). (Taf. IV.)

„ 22. GOETHART: Beiträge zur Kenntniss des Malvaceen-Androeciums (continued in Nos. 23–26). (Taf. V.)

„ 27. SCHERFFEL: Zur Frage 'Sind die den Höhlenwänden aufsitzenden Fäden in den Rhizomschuppen von *Lathraea squamaria*, L., Secrete oder Bacterien?'

„ 28. JOST: Die Zerklüftungen einiger Rhizome u. Wurzeln [continued in Nos. 29–32). (Taf. VI.)

„ — FÖRSTER: Ueber Vorkommen mit einander verwachsener Körner von *Hordeum vulgare*.

„ 33. BEYERINCK: L. Beissner's Untersuchungen bezüglich der Retinisporafrage (continued in No. 34).

Botanische
Beiheft No. 35.

Botanische (*continued*).

KLEBS : Einige Bemerkungen über die Arbeit von Went 'Die Entstehung der Vacuolen in den Fortpflanzungszellen der Algen.'

„ 36. LOEW : Ueber die Metamorphose vegetativer Sprossanlagen in Blüthen bei *Viscum album.*

„ 37. WORTMANN : Ueber den Nachweis, das Vorkommen u. die Bedeutung des diastatischen Enzyms in den Pflanzen (continued in Nos. 38-41).

„ 38. KOCH : Zur Kenntniss der Fäden in den Wurzelknöllchen der Leguminosen.

„ 42. FISCHER : Ueber den Einfluss der Schwerkraft auf die Schlafbewegungen der Blätter (continued in Nos. 43, 44).

„ 45. BEYERINCK : Culturversuche mit Zoochlorellen, Lichenengonidien u. anderen niederen Algen (continued in Nos. 46–48). (Taf. VII.)

„ 48. CHIMELEVSKY : Eine Notiz über das Verhalten der Chlorophyllbänder in den Zygoten der *Spirogyra*-arten. (Taf. VIII.)

„ 49. SOLMS-LAUBACH : Ueber die Fructification von *Bennettites Gibsonianus*, Carr. (continued in Nos. 50–52). (Taf. IX, X.)

„ 52. BEYERINCK : Künstliche Infection von *Vicia Faba* mit *Bacillus radicicola.*

GREAT BRITAIN.

Album, The Orchid. (London, 1890.)

Vol. IX (*continued*) contains plates of—*Cypripedium Elliottianum*, Rchb. f.; *Dendrobium Brymerianum*, Rchb. f.; *Disa Graminifolia*, Banks; *Cypripedium Asburtoniae superbum*, Hort.; *Laelia Dormantiana*, Rchb. f.; *Calanthe Mylesii*, hybr.; *Odontoglossum Alexandrae Outramii*, Hort.; *Cattleya maxima Marchettiana*, Hort.; *Oncidium Larkinianum*, Gower; *Odontoglossum Youngii*, Gower; *Dendrobium album*, Wight; *Lycaste gigantea*, Lindl.; *Vanda teres candida*, Rchb. f.; *Zygopetalum crinitum caeruleum*, Hort.; *Dendrobium Schneiderianum*, Rchb. f.; *Miltonia* (*Odontoglossum*) *Bleuana splendens*, Bleu; *Laelia elegans Broomeana*, O'Brien; *Odontoglossum Alexandrae plumatum*, Hort.; *Brassavola glauca*, Bateman; *Phalaenopsis intermedia Brymeriana*, Rchb. f.; *Odontoglossum Uro-Skinneri*, Lindl.; *Cypripedium Marshallianum*, Rchb. f.; *Dendrobium Chrysotis*, Rchb. f.; *Cypripedium Oenanthum superbum*, Hort.

Annals of Botany. Vol. IV (*continued*).

No. XIII. MASSEE : A monograph of the British Gastromycetes. (Plate I–IV.)

BARBER : On a change of flowers to tubers in *Nymphaea Lotus*, var. *monstrosa.* (Plate V.)

BATESON : On the change of shape exhibited by turgescent pith in water.

WAGER : Observations on the structure of the nuclei in *Peronospora parasitica* during formation of the oospore.

SCOTT : On some recent progress in our knowledge of the Anatomy of Plants.

Notes—GARDINER : A new application of photography to the demonstration of certain physiological processes in plants.

MASTERS : Double-flowered *Ceanothus.*

BOWER : On Dr. Macfarlane's observations on Pitchered Insectivorous plants. (Woodcuts 1–3.)

——— : Attempts to induce aposporous developments in Ferns.

Annals of Botany (*continued*).

KEAN: A lily-disease in Bermuda.

——: The onion-disease in Bermuda.

BENNETT: A Hybrid Desmid. (Woodcut 4.)

——: Vaucheria-galls. (Woodcut 5.)

FARMER: The stomata in the fruit of *Iris pseudacorus*, L. (Woodcuts 6–13.)

JOHNSON: *Mystropetalon Thomii*, Harv.

No. XIV. ATKINSON: Monograph of the *Lemaneaceae* of the United States. (Plates VII–IX.)

WILSON: The Mucilage- and other glands of the *Plumbagineae*. (Plates X–XIII.)

SCOTT-ELLIOT: Note on the fertilisation of *Musa*, *Strelitzia reginae*, and *Ravenala madagascariensis*. (Plate XIV.)

——: Ornithophilous flowers in South Africa. (Plate XV.)

LISTER: Notes on *Chondrioderma difforme* and other Mycetozoa. (Plate XVI.)

Notes.—HARTOG: On cortical fibro-vascular bundles in some species of *Lecythideae* and *Barringtonieae*.

BENNETT: Vaucheria-galls.

No. XV. OLIVER: On *Sarcodes sanguinea*, Torr. (Plates XVII–XXII.)

RIDLEY: On the method of fertilization in *Bulbophyllum macranthum* and allied Orchids. (Plate XXII A.)

HARTOG: A Monadine parasite on Saprolegnieae. (Plate XXII B.)

BOWER: On antithetic as distinct from homologous Alternation of Generations in Plants.

Notes.—VAIZEY: Alternation of generations in Green Plants.

DRUCE: *Spergula pentandra*, L., as an Irish plant.

GREEN: On the changes in the endosperm of *Ricinus communis* during germination.

Bulletin of Miscellaneous Information, Kew. 1890.

No. 37. The Weather plant (*Abrus precatorius*, L.).

„ 38. Manufacture of Quinine in India.

„ — Maqui berries (*Aristotelia Maqui*) for colouring wine.

„ — Vine culture in Tunis.

„ — Phylloxera in Victoria.

„ — Botanical exploration of Cuba.

„ — The sugar production of the world.

„ 39. Indian Yellow.

„ — Bombay Aloe fibre (*Agave vivipara*, L.).

„ — Commercial value of Loxa bark (*Cinchona officinalis*, L.).

„ — Barilla (*Halogeton sativus*, Maq.)

„ 40. Canaigre (*Rumex hymenosepalum*, Torr.).

„ — Pistachio cultivation in Cyprus.

„ 41. Lagos Rubber (*Ficus Vogelii*, Miq.).

„ — Siberian Perennial Flax (*Linum perenne*, L.).

„ 42. Timber trees of Straits Settlements.

„ — Cotton in West Africa.

„ 43. West African Annatto (*Bixa Orellana*, L.).

Bulletin of Miscellaneous Information, Kew (*continued*).
No. 43. — Colombian India-rubber (*Sapium biglandulosum*, Muell. Arg.).
" — Fibre Industry at the Bahamas (*Agave rigida*, var. *Sisalana*).
" 44. — Natal Aloes.
" — Gambia Mahogany (*Khaya senegalensis*, A. Juss.).
" — Ceylon Cacao (*Theobroma cacao*, L.).
" — Chesnut flour (*Castanea sativa*, Mill.).
" 45. Prickly pear in South Africa.
" — Jarrah timber (*Eucalyptus marginata*, Sm.).
" — Economic plants of Madagascar.
" 46. An edible fungus of New Zealand (*Hirneola polytricha*, Mont.).
" — Mexican fibre or Istle.
" — A Forest Plague in Bavaria (*Liparis Monacha*).
" — Akro fibre (*Hibiscus esculentus*, L.).
" — Cocoa-nut butter (*Cocos nucifera*, L.).
" 47. Siberian Coffee (*Coffea siberica*, Bull.).
" — Cola-nut (*Cola acuminata*, R. Br.).
" 48. Banana disease in Fiji.
" — Fibre productions in the Caicos.

Bulletin of the Botanical Department, Jamaica. (Jamaica, 1889–90.)
No. 15. Cinchona Bark.—Sisal Hemp.—Coca.
" 16. Coca.
" 17. CROSS: Miscellaneous Fibres.
" 18. Ferns: Synoptical List (continued in No. 20).
" 19. Sugar Cane Seedlings.
" 20. GAMBIER: Cultivation of Cacao.

Chronicle, The Gardeners'. (London, 1890.)
Vol. VII (Third Series).
No. 158. ROLFE: *Aërides Augustianum*, n. sp.
" — ———: *Cypripedium Niobe*, n. hyb.
" — A Gardener's Problem—Plant Culture (continued in Nos. 159–167).
" 159. WEATHERS: *Angraecum Ichneumoneum*, Lindl.
" — LYNCH: *Iris Bakeriana*.
" — ROLFE: *Aërides suavissimum* and its varieties.
" 160. ———: *Cypripedium* '*Buchananianum*' ×.
" — ———: Hybrid Calanthes.
" — HEMSLEY: A tree Solanum (*S. macranthum*). (Fig. 13.)
" — FOSTER: *Iris Bakeriana*.
" — *Darlingtonia Californica*. (Figs. 14, 15.)
" 161. ROLFE: *Cypripedium Hera* × n. hyb.
" — *Pyrus heterophylla*. (Fig. 18.)
" 162. ROLFE: *Calanthe Veitchii alba* × *Phalaenopsis Cynthia* × nat. hyb.
" — *Lycaste lasioglossa*, Rchb. f.
" 163. BROWN: *Cypripedium* 'Northumbrian,' n. hyb.; *C. Lecanum*, var. *biflorum*, n. var.
" — ROLFE: *Cypripedium Siamense*, n. sp.
" — *Laelia Gouldiana*. (Fig. 28.)
" — F. R.: Epiphyllums and their propagation. (Fig. 29.)
" 164. BAKER: *Colchicum procurrens*, n. sp.

Chronicle, The Gardeners' (*continued*).

No. 164. ANDERSON: *Odontoglossum Pescatorei* (with Plate).
„ 165. WATSON: Fragrance in Ferns.
„ — ROLFE: *Trichopilia punctata*, n. sp.
„ — Hybrid Rocheas. (Fig. 35.)
„ — *Aërides Augustianum.* (Fig. 36.)
„ — BROWN: *Cypripedium Plunerum* and *C. doliare.*
„ — SMITH: Action of light on a Saxifrage.
„ 166. WILLIS: Manures.
„ — ROLFE: *Cypripedium Oenone*, n. hyb.
„ — U. D.: Species of *Eriogonum.* (Figs. 38–40.)
„ — BURBIDGE: *Galanthus*, spp. (Figs. 41–3.)
„ 167. ————: Gigantic Orchids. (Fig. 46.)
„ — BAKER: *Fritillaria* (*Amblirion*) *canaliculata*, n. sp.
„ — ROLFE: *Xylobium Colleyi*, Rolfe.
„ — Nomenclature of Orchids.
„ — BURBIDGE: Successive growth of Corms in *Montbrettia Pottsii.*
„ 168. BROWN: *Eupatorium probum*, n. sp., *Arisaema anomalum*, Hemsl.
„ — MEEHAN: How to tell the age of trees.
„ — *Taxodium distichum.* (Figs. 49 and 50, showing the 'Knees.')
„ 169. ROLFE: *Zygopetalum* (*Bollea*) *Whitei*, n. sp.; *Odontoglossum Wattianum*, n. hyb.?
„ — DEWAR: *Iris Sindjarensis*, Boiss. and Haussk., sp. nov. (Fig. 55.)
„ 170. The fingered Citron (*Citrus japonica*). (Figs. 56, 58–60.)
„ — *Phajus Cooksoni* × n. hyb. (Fig. 57); *Angraecum primulinum*, nat. hyb.
„ — New hybrid Narcissus.
„ 171. HUDSON: Effect of Fog on Plants.
„ — *Eucharis Bakeriana*, N. E. Brown, n. sp. (Fig. 61); *Masdevallia Lowii*, Rolfe, n. sp.
„ — *Prepusa Hookeriana.* (Fig. 62.)
„ — HEMSLEY: The genus *Asarum.*
„ — SMITH: Truffles—True and False (continued in Nos. 174, 176).
„ 172. HEMSLEY: *Paulownia Fortunei*, n. sp.
„ — ROEBELEN: *Phalaenopsis* in the Philippine Islands.
„ 173. DRUERY: Vagaries of Variation, with special reference to British Ferns (continued in No. 174).
„ 174. Colouring of Grapes.
„ — ROLFE: *Dendrobium atroviolaceum*, n. sp.
„ — ———: Hybrid Odontoglossums.
„ — ———: *Phalaenopsis* in the Philippines.
„ 175. MACFARLANE: Microscopic structure of Hybrids.
„ — ROLFE: *Zygopetalum caulescens*, n. sp.
„ — ———: A complex Cypripedium hybrid—*Odontoglossum Horsmani* × Rchb. f.
„ — GAMMIE: Orchids in Sikkim.
„ 176. BAKER: *Pteris ensiformis*, Burm., var. *Victoriae*, Hort. Bull.
„ — RIDLEY: *Calanthe* (s. *Preptanthe*) *rubens*, n. sp.
„ — SIMMONDS: The economic uses of leaves.
„ 177. ROLFE: *Dendrobium* × *Venus*, n. hyb.—*Cypripedium* × *Numa*, n. hyb.
„ 178. BAKER: *Tulipa ciliatula*, n. sp.

Chronicle, The Gardeners' (*continued*).
No. 178. Brown: *Eucharis Stevensi* ×.
" — Soppitt: The Lily of the Valley Fungus.
" — Orchid Nomenclature.
" 179. *Abies bracteata.* (Fig. 112.)
" — Rolfe: *Bulbophyllum leminiscatoides*, n. sp.
" — Watson: Natural conditions *v.* culture: Pleiones.
" 180. Baker: *Lathyrus Sibthorpii*, Baker.
" — Rolfe: *Zygopetalum Iorisianum*, n. sp.—*Scaphosepalum antenniferum*, n. sp.
" — Tuberous branches. (Figs. 116–118.)
" 181. Druery: Notes from Mexico.
" — Brown: *Catasetum Bungerothi.*
" — Rolfe: *Cattleya labiata*, Lindl., var. *Warocqueana*, n. var. (?).
" 182. ———: *Cattleya* × *intricata*, Rchb. f., var. *maculata*, n. var.
" — Kean: The Lily disease.
" — *Disa tripetaloides.* (Fig. 127.)
" 183. *Dendrocalamus Sikkimensis.* (Fig. 130.)
" — Rolfe: *Cypripedium Aylingi* × (Fig. 131) *C. Vipani* × n. hyb.
" — Willis: Growth of Leguminous plants.
Vol. VIII.
" 184. Rolfe: *Moorea irrorata*, n. gen. and sp.
" — Plants as they grow in nature.
" — Rolfe: *Cattleya* × *Krameriana*, Rchb. f.—*Odontoglossum Galeottianum*, Rich. & Gal.
" 185. Brown: *Alocasia reversa*, n. sp.—*Cypripedium* 'Elinor,' n. hyb.
" — Plowright: British Uredineae.
" 186. Rolfe: *Cypripedium Hookerae*, Rchb. f., var. *volonteanum*, n. var.; *Aerides I'Ansoni*, hyb. nat. (?)
" — Bonavia: Acclimatisation.
" 187. Baker: *Hemerocallis aurantiaca*, n. sp.; *H. Thunbergii*, Baker, Hort.
" — Rolfe: *Maxillaria longisepala*, n. sp.
" — Macfarlane: *Cytisus Adami* × (Anatomy of).
" 188. Baker: *Gladiolus primulinus*, n. sp.
" — Rolfe: A double Orchid: *Epidendrum vitellinum flore pleno.*
" — Green-flowered regular Antirrhinums.
" — The Colours of Flowers.
" 189. Baker: *Hippeastrum* (*Habranthus*) *brachyandrum.*
" — Brown: *Pelargonium saxifragoides*, n. sp.
" 190. The American Locust tree (*Robinia pseudacacia*).
" — *Musa Seemannii.* (Fig. 28.)
" — Baker: *Billbergia vexillaria* × André; *Nidularium striatum*, Hort. Bull.
" — Rolfe: *Masdevallia costaricensis*, n. sp.
" — M. T. M.: *Nepenthes Burkeii*, Mast., var. *prolifica.*
" — Fern Nomenclature.
" 191. Rolfe: *Coryanthes Bungerothii*, n. sp.
" — Brown: *Gladiolus decoratus*, Baker.
" — The Hollyhock Fungus. (Figs. 33–35.)
" — Fertilisation without Pollen.

Chronicle, The Gardeners' (*continued*).

No. 192. MASTERS: *Nepenthes stenophylla*, n. sp.
„ 193. ROLFE: *Masdevallia guttulata*, n. sp.
„ — Scented and other New Zealand Ferns.
„ — FRIEND: Herb Paris and its Foe (*Aecidium*, sp.). (Figs. 45, 46.)
„ — Securing Fertilisation in Cereals.
„ 194. BROWN: Three new hybrid Cypripediums, *C. Alfred*, *C. Alice*, *C. Constance*.
„ — BONAVIA: Fertilisation without Pollen.
„ — The Living Earth (continued in Nos. 195–6).
„ 195. ROLFE: *Masdevallia fulvescens*, n. sp. (Fig. 65); *M.* × *Stella*, n. hyb.
„ — New disease of Hollyhocks.
„ — Orchids in Panama.
„ 196. ROLFE: *Laelio-Cattleya* × *Proserpine*, n. hyb.; *Cattleya* (*labiata*) *Gaskelliana picta*, n. var.
„ 197. ———: *Sobralia Lowii*, n. sp.; *S. Wilsoniana*, n. sp.; *Masdevallia* × *Measuresiana*, n. hyb.
„ — *Lilium Henryi*. (Fig. 75.)
„ 198. ROLFE: *Cypripedium* × *H. Ballantine*, n. hyb.
„ — BAKER: *Barbacenia squamata*. (Fig. 81.)
„ — SMITH: Disease of Orchids (*Cladosporium Orchidearum*). (Fig. 82.)
„ — WATSON: *Streptocarpus* hybrids.
„ — GOLLAN: Acclimatisation in India (continued in Nos. 200–1).
„ — Germination of *Lodoicea Seychellarum*. (Fig. 84.)
„ 199. BROWN: *Haemanthus Lindeni*, n. sp.
„ 200. *Pinus Montezumae*. (Figs. 91–4, 96.)
„ — GAMBLETON: *Begonia Baumanni*, n. sp.
„ — ROLFE: *Angraecum Henriquesianum*, n. sp.
„ 201. MASTERS: *Aristolochia longecaudata*. (Fig. 98.)
„ — ROLFE: *Sobralia Sanderae*, n. sp.
„ 202. BAKER: *Gladiolus Kirkii*, n. sp.
„ — ROLFE: *Masdevallia O'Brieniana*, n. sp.
„ — DAMMER: *Eriogoneae*. (Figs. 103–5.)
„ — ROLFE: *Laelio-Cattleya* × *Cassandra*, Rolfe.
„ — *Howeia* (*Kentia*) *Forsteriana*. (Fig. 106.)
„ 203. ROLFE: *Oncidium Leopoldianum*, n. sp.
„ — M. T. M.: *Pinus ponderosa*. (Figs. 110, 111, 114, 115.)
„ — SEWELL: *Agave attenuata*.
„ — Two Chinese Introductions (*Primula* and *Chrysanthemum*).
„ 204. The Chile Pine (*Araucaria imbricata*). (With Plate and Figs. 117, 118.)
„ — ROLFE: *Sophro-Cattleya* × *Calypso*, n. hyb.
„ — O'BRIEN: *Cattleya granulosa*, var. *Buyssoniana*, n. var. (Fig. 116.)
„ 205. ROLFE: *Dendrobium* × *Cassiope*, n. hyb.; *Cattleya superba*, var. *alba*, n. var.
„ — *Decaschistia ficifolia*. (Fig. 122.)
„ — MANDA: *Cypripedium Arnoldianum*, n. hyb. (Fig. 123.)
„ 206. BROWN: Hybrid Anthuriums, *A. Hero* ×, n. hyb.
„ — ROLFE: *Cypripedium insigne Macfarlanei*, n. var.
„ — SMITH: Spot on Grapes (*Glaeosporium laeticolor*). (Fig. 125.)
„ 207. O'BRIEN: *Cattleya Rex*, n. sp.

Chronicle, The Gardeners' (*continued*).
No. 207. Brown: *Crassula recurva*, n. sp.
" — M. T. M.: *Abies Fraseri*. (Fig. 132.)
" 208. Druery: Abnormal growth of *Adiantum*. (Fig. 137.)
" — Rolfe: *Cypripedium* × *Antigone*, n. hyb.; *C.* × *Doris*, n. hyb.
" — O'Brien: *Laelia anceps Thomsoniana*, n. var.
" — Hudson: Fogs and Vegetation.
" — *Cypripedium longifolium*, and *C. Lowii*. (Figs. 143–4.)
" 209. Kränzlin: *Rodriquezia Fuerstenbergii*, n. sp.
" — Rolfe: *Cypripedium* × *Eyermanianum*, n. hyb.
" — *Abies concolor*. (Figs. 147–151.)

Grevillea. (London, 1890.) Vol. XVIII.
No. 87. Cooke: Australian Fungi (*continued*) (continued in Nos. 88–90).
" — Elliott: Fungi of Madagascar.
" — Cooke: New British Fungi (*continued*) (continued in Nos. 88–90).
" — ———: Fungi of Java.
" — ———: Synopsis Pyrenomycetum (*continued*) (continued in No. 88).
" — Massee: British Pyrenomycetes (*continued*) (continued in Nos. 88–90).
" — Crombie: Index Lichenum Britannicorum.
" 88. Phillips: British Discomycetes (Notes and Additions).
" — Cooke: Some Exotic Fungi.
" — ———: On *Campbellia*, gen. nov.
Vol. XIX.
" 89. Cooke: New Zealand Fungi (continued in No. 90).
" — ———: Some African Fungi.
" — ———: Some Asiatic Fungi.
" — ———: North American Fungi.
" — British Thelephorei (continued in No. 90).
" 90. Cooke: Controverted Agarics.
" — *Sclerodepsis*, gen. nov.

Icones Plantarum (Hooker's). Vol. X.

Part I contains Plates and Descriptions of—*Caralluma lutea*, N. E. Br., n. sp.; *C. armata*, N. E. Br., n. sp.; *C. linearis*, N. E. Br., n. sp.; *C. dependens*, N. E. Br., n. sp.; *C. ramosa*, N. E. Br.; *C. aperta*, N. E. Br; *Huernia humilis*, Haw.; *H. primulina*, N. E. Br., n. sp.; *Stapelia horizontalis*, N. E. Br., n. sp.; *S. variegata*, L., vars. (description only); *S. Namaquensis*, N. E. Br.; *S. Barklyi*, N. E. Br., n. sp.; *S. intermedia*, N. E. Br., n. sp.; *S. virescens*, N. E. Br., n. sp.; *S. villosa*, N. E. Br., n. sp.; *S. affinis*, N. E. Br., n. sp.; *S. fuscopurpurea*, N. E. Br., n. sp.; *S. patula*, Willd., var. *longirostris*, N. E. Br.; *S. Arnoti*, N. E. Br., n. sp.; *S. Desmetiana*, N. E. Br.; *S. glabricaulis*, N. E. Br., n. sp.; *S. tsomoensis*, N. E. Br.; *S. lucida*, DC.; *S. Macowani*, N. E. Br., n. sp.; *S. erectiflora*, N. E. Br.; *S. rufa*, Mass.; *S. parvipuncta*, N. E. Br., n. sp.; *Piaranthus grivanus*, N. E. Br., n. sp.; *P. comptus*, N. E. Br., n. sp.; *Duvalia angustiloba*, N. E. Br.; with a key to all the genera of the Tribe *Stapelieae*.

Part II contains Plates and Descriptions of—*Tilia Tuan*, Szyszyl.; *T. Henryana*, Szyszyl., n. sp.; *T. Oliveri*, Szyszyl., n. sp. (description only); *Tapiscia sinensis*, Oliv., n. gen. et sp.; *Fraxinus*

Icones Plantarum (*continued.*)

platypoda, Oliv., n. sp.; *F. retusa*, Champ., var. *Henryana*; *Sycopsis sinensis*, Oliv., n. sp.; *Streptopus paniculatus*, Baker, n. sp.; *Cephalotaxus Griffithii*, Hook. f.; *Schizophragma integrifolia*, Oliv., n. sp.; *Calathodes palmata*, Hook. f. & Thoms.; *Fagus sylvatica*, L., var. *longipes*; *Dicentra macrantha*, Oliv., n. sp.; *Cyclea racemosa*, Oliv., n. sp.; *Aloe kniphofioides*, Baker, n. sp.; *Dermatobotrys Saundersii*, Bolus, n. gen. et sp.; *Vaccinium Exul*, Bolus, n. sp.; *Tysonia Africana*, Bolus, n. gen. et sp.; *Populus lasiocarpa*, Oliv., n. sp.; *Oreocharis Henryana*, Oliv., n. sp.; *Clematis formosana*, O. Kuntze, n. sp.; *Apios macrantha*, Oliv., n. sp.; *Rubus malifolius*, Focke, n. sp.; *R. simplex*, Focke, n. sp.; *Heteropsis Jenmani*, Oliv., n. sp.; *Eucommia ulmoides*, Oliv., n. gen. et sp.

Vol. XI (devoted to Indian Orchidaceae).

Part I contains Plates and Descriptions of species of—*Microstylis*, *Titania*, *Oberonia*, *Liparis*, *Platyclinis*, and *Dendrobium*, including the following new species—*Oberonia Mannii*, Hook. f.; *O. insectifera*, Hook. f.; *O. rosea*, Hook. f.; *Liparis Dolabella*, Hook. f.; *L. gracilis*, Hook. f.; *L. robusta*, Hook. f.; *L. tenuifolia*, Hook. f.; *L. torta*, Hook. f.

Part II contains Plates and Descriptions of species of *Dendrobium* and *Bulbophyllum*.

Journal and Transactions, The Pharmaceutical. (London, 1890.)

No. 1019. DRUCE: Herbaria.
„ — SADTLER: The Synthesis of Alkaloids.
„ — BAINBRIDGE AND MORROW: Aloes.
„ 1025. *Kraussia coriacea*, a reputed poisonous plant of Natal.
„ — *Cinnamomum Cassia*.
„ — Oil of Lavender.
„ 1029. KEMP: Notes on recent researches on the Oil of Betel Leaves.
„ 1033. MILLARD: Examination of the 'Cream of Tartar Fruit' from Pretoria.
„ 1035. MAIDEN: The Chemistry and Commercial Possibilities of Wattle Gum (continued in No. 1040).
„ 1036. New Alkaloid from *Scopolia atropoides*.
„ 1041. DYMOCK AND WARDEN: *Luffa echinata*, Roxb.
„ 1042. GERRARD AND SYMONS: Ulexine and Cytisine.
„ — HOLMES: Note on *Scopolia Hladnikiana*.
„ 1045. WARDEN: Note on the Fruit of *Erythroxylon Coca*.
„ — MAIDEN: *Macrozamia* (*Encephalartos*) Gum.
„ — LUBBOCK: The Shapes of Leaves and Cotyledons.
„ 1047. Distribution of Solanine and its Micro-chemical Reactions.
„ 1048. PAUL AND COWNLEY: Amount of Theine in Tea.
„ — Chemotactic sensitiveness of Zoospores.
„ 1051. HUMPHREYS: Chinese Cinnamon.
„ 1052. HOOPER: Sweet Pellitory.
„ — The Chemistry of Australian Products.
„ 1055. HOLMES: Curaçoa Aloes.
„ 1056. ———: Note on *Strophanthus hispidus*.
„ — CHRISTY: Note on leaves of a plant yielding Onabain.
„ 1057. Alkaloids of White Hellebore.
„ — *Oroxylum Indicum*, and chemical examination of the Bark.

Journal and Transactions, The Pharmaceutical (*continued*).

No. 1064. Umney: Laboratory Notes of Extracts of Malt.
" — Hooper: Chemical Notes on Mannas.
" 1067. Mootooswamey: The uses of Curry Leaves.
" 1069. Hooper: Leaves of *Strychnos Nux-Vomica.*
" 1070. Maiden: The Gum of the Leopard tree (*Flindersia maculosa*, F. v. M.).
Derrid (from *Derris elliptica*).

Journal of Botany. (London, 1890.) Vol. XXVIII.

No. 325. Hemsley: On an obscure species of *Triumfetta.* (Plate 293.)
" — Marshall: *Epilobium* Notes for 1889.
" — Jack: Marine Algae of the Arbroath district.
" — Baker, E. G.: Synopsis of Genera and Species of Malveae (continued in Nos. 329, 331, 332, 335, and 336).
" — Clarke: *Cyperus Jeminicus*, Rottb.
" — Britten and Boulger: Biographical Index of British and Irish Botanists (*continued* from Vol. XXVII and continued in Nos. 326–330, 332–336).
Short Notes:—Some North Devon *Rubi*; New Records for Scotland.
" 326. Massee: A Monograph of the Genus *Podaxis*, Desv. (= *Podaxon*, Fr.) (continued in No. 327). (Plates 294, 295.)
" — Druce: Notes on Scotch Plants.
" — Marshall: On *Festuca heterophylla*, Lam.
Short Note:—Wilts Plants.
" 327. Groves, H. and J.: Notes on the British Characeae for 1887–9. (Plate 296.)
" — Bennett, A.: Further Records from Iceland.
" — Hamilton and Glascott: Plants found near Kilmarnock, Co. Wexford.
Short Notes: A *Potamogeton* Note; *Potamogeton Tuckermani*, Robbins; *Pringsheimia*, Rke.
" 328. Focke: Notes on English *Rubi* (continued in No. 329).
" — Baker, J. G.: Vascular Cryptogamia of New Guinea, collected by Sir W. Macgregor.
" — Scully: Plants found in Kerry, 1889.
Short Notes:—Middlesex Plants; *Sciadium arbuscula*, A. Braun; *Crepis foetida*, L., in Northamptonshire.
" 329. Rolfe: The Genus *Scaphosepalum*, Pfitzer.
" — Fryer: Notes on Pondweeds.
" — Hope: A new *Lastrea* from Assam.
" — Holmes: Marine Algae of Devon.
" — The Genera of Stapelieae.
Short Notes:—*Lejeunea Rossettiana*, Massal; Glamorgan Plants; Buda v. Tissa.
" 330. Baker, E. G.: New Plants from the Andes. (Plate 297.)
" — Townsend: Notes on a new subspecies of *Euphrasia officinalis*, L.
" — Focke: Short descriptive Notes of three *Rubi.*
" — Linton, E. F. and W. R.: Aberdeen, Forfar, and Dumfries Plantnotes.
" — Bailey: *Carex rigida*, Good., and its varieties.
" — Fryer: Supposed Hybridity in *Potamogeton.*

Journal of Botany (*continued*).

No. 330. MARSHALL AND HANBURY: Notes on Highland Plants.
Short Notes: *Lepidium Draba*, L., in Wales; *L. ruderale*, L., in Carnarvonshire; *Chara fragilis*, Desv., in Denbighshire.

„ 331. WILLIAMS: Synopsis of the genus *Tunica*.

„ — SCULLY: Hepaticae found in Kerry, 1889.

„ — BEEBY: On *Potamogeton fluitans*, Roth.

„ — BRIGGS: *Rubus erythrinus*, Genev.

„ — SOPPITT: *Puccinia digraphidis*, n. sp.
Short Notes:—*Rumex propinquus*, J. E. Aresch., in Britain; *Pavonia hastata*, Cav.; *Lepidium Draba*, L., in South Wales; *Carex tomentosa*, L., in East Gloucester; Kent Plants; *Scapania planifolia*, Hook.; *Potamogeton falcatus*.

„ 332. FRYER: Notes on Pondweeds.

„ — DRUCE: Notes on Oxford Plants.

„ — BEEBY: On *Sparganium*.

„ — MCARDLE: Additions to the Irish Moss Flora.
Short Notes:—*Crepis taraxacifolia* in Sussex; *Potentilla maculata*, Pourr., in Dumfries; Merionethshire Plants; *Potamogeton fluitans*, Roth.

„ 333. BARCLAY: On some Rusts and Mildews in India. (Plate 298.)

„ — BAKER, J. G.: Tonquin Ferns.

„ — FEER: Campanularum novarum Decas Prima.

„ — BRIGGS: *Rubus silvaticus*, W. & N.
Short Notes:—*Arabis albida* naturalised in Derbyshire; *Ranunculus ophioglossifolius* in East Gloucestershire; Flora of Suffolk; *Arenaria gothica*, Fries.

„ — CARRUTHERS: Report of the Department of Botany, British Museum, for 1889.

„ 334. WILLIAMS: Plants described by Arduino (1759–1763).

„ — BENNETT, A.: The Nomenclature of Potamogetons.

„ — BRITTEN: *Spergula pentandra* in Ireland.

„ — The Fertilisation of the Sugar-cane.

„ — BAKER, J. G.: New Guatemalan *Bromeliaceae*.
Short Notes:—*Crepis nicaeensis*, Balb., in Beds.; *Brachypodium pinnatum* in Bucks.; *Hypnum circinale*; *Helianthemum guttatum* in Anglesea; *Trientalis Europaea* in Foula; *Dianthus caesius*, Sm.; Flora of Somerset.

„ 335. FRYER: On a new hybrid *Potamogeton* of the *fluitans* group. (Plate 299.)

„ — HOPE: Three new Lastreas from Assam.

„ — ROY: Fresh-water Algae of Enbridge Lake and vicinity, Hampshire.

„ — BABINGTON: *Rubus Dumnoniensis*, n. sp.

„ — DRUCE: *Spergula pentandra* in Ireland.
Short Notes:—*Drosera anglica* in Hants.; Bedfordshire and its Droseras; *Malva borealis* in Kent; *Carex montana*, L., in North Somerset; *Rubus silvaticus*, W. & N.; *Rosa micrantha*, Sm., var. *Briggsii*, Baker; Welsh Records.

„ 336. MCARDLE: Hepaticae of Loughbray, Co. Wicklow.

„ — BUTLER: New Stations of Irish Plants.

„ — ELLIOT: The Genus *Xysmalobium*.

Journal of Botany (*continued*).

No. 336. ROBERTS: Introduced Plants in West Cornwall.

„ — Short Notes:—*Hieracium holophyllum*, n. sp.; Autumn Flowering of *Mercurialis perennis*; Additions to the Flora of Wilts.; *Papaver hybridum* in Denbighshire.

Journal of the Linnean Society (Botany). (London, 1890.)

Vol. XXV (*continued*).

No. 172. BAKER: Further contributions to the Flora of Madagascar (*concluded*). (Plates L–LIII.)

„ — HEMSLEY: Report on Botanical Collections from Christmas Island.

„ — MOORE: Studies in Vegetable Biology: V. *Apiocystis* a Volvocinea, a Chapter in Degeneration. (Plates LIV–LVI.)

„ — MORRIS: On the Characteristics of Plants included under *Erythroxylon Coca*, Lam. (With 2 Woodcuts.)

„ — MACOWAN: New Cape Plants.

„ — COSTERUS: On Malformations in *Fuchsia globosa*.

„ — LISTER: Notes on the Ingestion of Food-material by the Swarm-cells of Mycetozoa. (With 1 Woodcut.)

Vol. XXVI.

„ 174. FORBES AND HEMSLEY: 'Index Florae Sinensis,' Pt. 8. (Pl. III–IV.)

„ 175. ——————: „ „ „ Pt. 9. (Pl. V–VI.)

Vol. XXVII.

„ 181. RIDLEY: Notes on the Botany of Fernando Noronha. (Plates I–IV.)

„ — MASSEE: A Monograph of the Thelephoreae, Pt. 2 (continued in No. 182). (Plates V–VI.)

„ 183–4. ROLFE: On the Sexual Forms of *Catasetum*, with special reference to the researches of Darwin and others. (Plate VIII.)

„ — MASTERS: Review of some points in the Comparative Morphology, Anatomy, and Life-History of the Coniferae. (With 29 Woodcuts.)

„ 185–6. WHITE: A Revision of the British Willows. (Plates IX–XI.)

Vol. XXVIII.

„ 189–91. COLLETT AND HEMSLEY: On a Collection of Plants from Upper Burmah and the Shan States. (Plates I–XXII and Map.)

„ 192. HENSLOW: On the Vascular Systems of Floral Organs and their importance in the Interpretation of the Morphology of Flowers. (Plates XXIII–XXXII.)

„ — MORRIS: On the Production of Seed in certain Varieties of the Sugar-cane (*Saccharum officinarum*, L.). (Plate XXXIII.)

Journal of the Marine Biological Association of the United Kingdom. (London, 1890.) New Series. Vol. I.

No. 3. JOHNSON: Flora of Plymouth Sound and adjacent waters. Preliminary Paper. (With a Woodcut.)

Journal of the Royal Agricultural Society of England. (London, 1890.) Third Series. Vol. I.

No. 1. LAWES: The Food of our Agricultural Crops.

„ — CARRUTHERS: Observations and Experiments on some English Pastures.

„ 2. FREAM: The Herbage of Pastures (with Map).

„ — GREEN: The Seed and its Germination.

„ 4. CARRUTHERS: The composition of some of the Ancient Pastures of England.

Journal of the Royal Horticultural Society. (London, 1889–90.)

Vol. XI (*continued*), Part 3.

FOSTER: On Irises.
BARRON: The Strawberry.
The National Rose Conference:—
BAKER: The Botany of Roses.
CRÉPIN: A new Classification of Roses.
HIBBERD: The Origin of the Florist's Carnation.
RIVERS: Peaches and Nectarines.
COLEMAN: On Conifers.

Vol. XII, Part 1.

The Vegetable Conference:—
WRIGHT: The Food of Vegetables.
The Chrysanthemum Centenary Conference:—
HEMSLEY: Wild Progenitors.
PAYNE: History of the *Chrysanthemum*.
BURBIDGE: Seeds and Seeding.

Part 2.

VEITCH: The *Hippeastrum* (*Amaryllis*).
Daffodil Conference:—
BURBIDGE: History of Cultivated Narcissi.
ENGLEHEART: Seedling Daffodils.
WOLLEY-DOD: Trumpet Daffodils.
KRELAGE: Polyanthus Narcissi.
WOLLEY-DOD: Primroses.

Part 3.

LYNCH: A new classification of the Genus *Paeonia*.
Carnation Conference:—
WILLIAMS: The Carnation from a botanical point of view.
Fern Conference:—
BOWER: Which are the oldest Ferns?
LOWE: Hybrid Ferns.
DRUERY; Plumose British Ferns.
Note on the Origin and Parentage of *Gladiolus Gandavensis*.

Journal of the Royal Microscopic Society. 1890. (Parts 1–5.)

Part 1. BENNET: Freshwater Algae and Schizophyceae of Hampshire and Devonshire. (Plate I.)
„ 3. WEST: Contribution to the Freshwater Algae of North Wales. (Plates V–VI.)
„ 4. GILL: On some methods of preparing Diatoms so as to exhibit clearly the nature of the Markings.
„ — CAUBER: On a simple form of Heliostat, and its application to Photomicrography.

Journal of the Transactions of the Victoria Institute. (London, 1889–90.)

Vol. XXII.

RIVERS: The Nectarine only a form or variety of the Peach.
POST: On the Botanical Geography of Syria and Palestine (with Map).

Journal of the Vol. IV. No. 27. GILL: On Diatom Structure.
" — RATTRAY: Revision of the Genus *Actinocyclus*.

Quekett Microscopical Club. (London, 1890.) Series 2,

Lancet, The. (London, 1889.)

No. 3462. WYNNE: On the distribution of the Leprosy Bacillus.

" 3469. WOODHEAD AND WOOD: Actions—Antidotal and Summative—that the products of Bacteria exert on the course of Infective Disease.

" 3482. FRASER: On the occurrence of the *Pneumococcus* in the Sputum from a case of Influenza.

" 3487. DOWDESWELL: Note on the Morphology of the Cholera Comma Bacillus.

" 3495. ANDERSON: The Malarial fever of Mauritius; its Microbic origin, &c.

" 3511. BENJAFIELD: *Eucalyptus globulus*.

Magazine, Botanical. (London, 1890.)

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„ — BAKER: *Carex strigosa* in W. Yorkshire.
„ 176. HICK: Ludwig Klein on the Genus *Volvox*.
„ 177. *Sparganium ramosum*, Huds., var. *microcarpa* in Yorkshire—*Ceterach officinarum* in the E. Riding.
„ 178. TUTE: Microscopic Fauna and Flora of Markington, Mid-West Yorks.
„ — MARTINDALE: The Lichens of Westmoreland (continued in No. 179).
„ 179. FOWLER: Lincolnshire Limestone Plants.
„ 180. BARNES: New Localities and Records for the Mosses of N. Yorks and S. Durham.
„ 181. ———: *Lejeunea rosettiana*, in N.W. Yorks.
„ — GOODCHILD: Some Flowering Plants and Ferns of Upper Swaledale.
„ —, *Ophrys apifera*, Huds., at Skipton.
„ 182. WHITWELL: New Station for *Arenaria Gothica*, in W. Yorks.
„ — *Senecio viscosus*, L., near Dewsbury.
„ 183. WHITWELL: Flowering Plants and Ferns of Upper Swaledale.
„ — *Ruppia rostellata*, in Cumberland.
„ 184. GRIMSHAW: Notes on the Flora of W. Cumberland.
„ 185. CROSSLAND: Fungi new to W. Yorks.
„ — *Lycopodium alpinum*, in W. Cumberland (a correction).

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COOKE: Suggestions on the Collecting and Study of the minute Fungi of Essex.

Nos. 4–6.

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No. 148. LEA: Oceanic Islands: Some account of the problems presented by their structure and natural history.
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„ 151. DRUCE: A tour through Spain, with special reference to the Flora of the Country.
„ — MATHEWS: History of the County Botany of Worcester (*continued*) (continued in Nos. 152–5).
„ — STONE: On Weismann's Theory of the Continuity of the Germ-Plasm (continued in No. 152).
„ 155. MOTT: Organic Death.

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" — RAY : On *Sciadium arbuscula*, Braun.
" — ——— : The Desmids of the Alford district.
" — WILSON : On the growth of *Phalaris arundinacea*.
" — BEEBY : On the Flora of Shetland.
" — STIRTON : On some Scotch Mosses of the Genus *Grimmia*.
" — TRAIL : Revision of Scotch Discomycetes (*concluded*) (v. No. 30 for Additions).
" — PHILLIPS : Descriptions of New Scotch Discomycetes.
" — TRAIL : New Records for Clyde. Scottish Galls.
" — ——— : On disappearance of Scotch Plants.
" — WHITE : *Agropyrum Donianum*, a correction.
" — DRUCE : *Agrostis canina*, L., var. *Scotica*, Hack.—*Pseudathyrium flexile*, Syme, in Easterness.
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" 29. WHITE : The Flora of River-Shingles.
" — ——— : Variety of *Cardamine amara*, L.
" — BEEBY : *Rumex propinquus*, T. E. Aresch. in Britain.
" — KEITH : *Agaricus storea*, Fr.
" — TRAIL : Revision of the Uredineae and Ustilagineae of Scotland (continued in No. 30).
" 30. WHITE : The Willows of the District of the N.-E. of Scotland Union of Naturalists' Societies.
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" 1056. HOLLIS : Galls. (See also Nos. 1059, 60, 68).
" 1058. WEISMANN : On his theory of Heredity.
" 1064. WELDON : Abnormal shoots of Ivy.
" 1065. HEMSLEY : The origin and composition of the Flora of the Keeling Islands.
" 1067. DAWSON : On certain Devonian Plants from Scotland.
" 1068. SMITH : A new green Vegetable colouring matter.
" 1069. MOORE : Nessler's Ammonia test as a Micro-chemical Reagent for Tannin.
Vol. XLII.
" 1073. LUBBOCK : The shapes of Leaves and Cotyledons.
" 1074. HARKER : The Corolla in Flower-fertilization (Blue Gentian).
" 1079. THOMSON : Spring Plants in New Zealand.
" 1080. Seedling Sugar-Canes.
" 1082. WALLACE : Birds and Flowers.
" 1083. HEMSLEY : Recent additions to the literature of Insular Floras.

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„ —— MUELLER: Highland Plants from New Guinea.
„ 1091. COCKERELL: Variability in the Number of Follicles in *Caltha*.
„ —— GARDINER, J. S.: Recent research among Fossil Plants.
„ 1095. The Teaching of Botany.
Vol. XLIII.
„ 1097. STRATTON: The Value of attractive characters to Fungi.
„ —— WATSON: The Coco-de-Mer Cultivation.
„ 1099. COOKE: Attractive Characters in Fungi.
„ 1103. J. S.: Attractive Characters in Fungi.

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„ — BRITTEN: The Disappearance of British Plants.
„ 2. FOWLER: Hampshire local names.
„ 4. ————: Yorkshire names.
„ 5. GORDON: The Toothwort (*Lathraea Squamaria*).
„ 7. WILLIAMS: The Cheddar Pink.
„ — DIXON: Northumbrian Plant names.
„ 8. HENSLOW: 'Mummy Wheat.'
„ 9. English Plant names.
„ 11. HENSLOW: The influence of the environment upon Plants.

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„ 289. WILLIAMSON: On the Organisation of the fossil plants of the Coal-measures. Part XVII.

„ — FRANKLAND, P. F. AND G. C.: The Nitrifying process and its specific ferment.

„ 290. WARD: The relation between host and parasite in certain Epidemic diseases of Plants.

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No. 292. KLEIN: A contribution to the Etiology of Diphtheria.

„ — MARTIN: The Chemical products of the Growth of *Bacillus anthracis* and their physiological action.

„ — HANKIN: A Bacteria-killing Globulin.

„ 294. GREEN: On the germination of the seed in the Castor oil Plant (*Ricinus communis*).

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Second Series.

Vol. I (Parts 1–3) contains coloured plates of:—*Cypripedium Morganiae Burfordiense*, Sdr., *Cattleya Bowringiana*, Veitch; *Dendrobium formosum*, Roxb.; *Phajus tuberculosus*, Blume; *Odontoglossum crispum Mundyanum*, Sdr.: *Laelia praestans*, Rchb. f.; *Dendrobium Phalaenopsis Statherianum*, Sdr.; *Cypripedium Botallii atrata*, Hort.; *Odontoglossum, Wattianum*, Rolfe; *Cypripedium hybridum lathamianum*, Sdr.; *Paphinia rugosa*, Rchb. f., and *Zygopetalum Xanthinum*, Rchb. f.; *Dendrobium* (*hybridum*) *melanodiscus*, Rchb. f.

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„ 304. Illustrations of Vegetable Teratology (illustrated) (continued in Nos. 305–9 and 311).

„ 305. COCKERELL: Weeds.

„ — MARQUAND: The Flora of Guernsey.

„ 307. COOKE: Trees and Plants as agents of denudation.

„ — WILSON: Observations on Plants during the Mild Winter of 1889–90.

„ 308. HAMILTON: The Stomata in *Orthotrichum* (illustrated).

„ — Some East Sussex Plants observed from 1884–1890.

„ 310. HAMILTON: The Leaf-Glands of *Pinguicula*.

„ 311. BALLANTYNE: Formation of Chlorophyll in Plants (*v.* 312).

„ — *Crepis taraxacifolia* in Sussex.

„ 312. RICHES: Notes on Senna (illustrated.)

„ — SLATER: The Evolution of Poisons in Plants.

„ — GRISEL: Abnormal development in the essential organs of *Papaver bracteatum*.

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HOLMES: Remarks on above.

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GRIEVE: List of Hepatics and Mosses collected in Rum Island, Hebrides, July, 1884.

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JOHNSTONE: *Ajuga pyramidalis* in Dumfriesshire.

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WHITE: Notes on some Willows in Edinburgh University Herbarium.

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TRAIL: Enumeration of Fungi collected in Hardanger in 1887.

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„ 2. ———: On the Fossil Plants in the Ravenhead Collection in the Free Library and Museum, Liverpool. (Pl. I and II.)

„ — ———: On some Fossil Plants from Teilia Quarry, Gwaenysgor, near Prestatyn, Flintshire (with 2 Plates).

„ 4. FRASER: *Strophanthus hispidus*: Its Natural History, Chemistry, and Pharmacology. Part 1. Its Natural History and Chemistry. (Pl. I–VII.)

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Part 2. WEBER: Etudes sur des Algues de l'Archipel Malaisien.

I. *Trentepohlia spongophila*, n. sp., et *Struvea delicatula*, Kütz. (Pl. XVI, XVII.)

II. *Phytophysa Treubii*, n. sp. (Pl. XXIV–XXVI.)

„ — ROBINSON: On the stem-structure of *Iodes tomentella*, Miq., and certain other Phytocreneae. (Pl. XVIII, XIX.)

Annales du Jardin Botanique de Buitenzorg (*continued*).

Part 2. BURCK: Ueber Kleistogamie im weiteren Sinne u. das Knight-Darwin'sche Gesetz. (Pl. XX–XXIII.)

Vol. IX.

Part 1. GOEBEL: Morphologische u. biologische Studien (*continued*).

IV. Ueber Javanische Lebermoose. (Pl. I–V.)

V. *Utricularia.* (Pl. VI–XV.)

VI. *Limnanthemum.* (Pl. XVI.)

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„ 3. OUDEMANS: Micromycètes nouveaux (with 2 Plates).

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Fasc. 1. LEONE: Nitrificazione e de-nitrificazione nella terra vegetale.

„ 12. PIROTTA: Sulla struttura anatomica della *Keteleeria Fortunei* (Murr.), Carr.

„ — ACQUA: Contribuzione alla conoscenza della cellula vegetale.

2° Semestre.

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LANZI: Le Diatomee fossili della Via Aurelia.

Sessione IV.

LANZI: Sui funghi della provincia di Roma (continued in No. VI).

CASTRACANE: Forma critica e nuova di *Pleurosigma* del Golfo di Napoli.

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CASTRACANE: La visione stereoscopica nello studio delle Diatomee.

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„ — SOMMIER: Della presenza di stipole nella *Lonicera coerulea*.
„ 3. ROSSETTI: Epaticologia della Toscana nord-ovest.
„ — BACCARINI: Primo catalagio di Funghi dell' Avellinese.
„ — SOMMIER: Nuove stazioni di piante in Toscana.
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„ — GOIRAN: Delle forme del genere *Potentilla* che vivono nella provincia di Verona. I.

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„ — ARCANGELI: Sui pronubi del *Dracunculus vulgaris*, Schott.

„ — ——: Sull' allungamento dei piccioli nelle foglie di *Euryale ferox*, Sal.

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„ — ——: Sullo sviluppo dei picnidii.

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„ — TANFANI: Una gita nelle alpi cadoriche.

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„ 2. AVETTA: Quarta contribuzione alla flora dello Scioa.

„ — ——: Quinta contribuzione alla flora dello Scioa.

„ — SOMMIER: Piante del Jardin della Mer de Glace.

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„ — ——: Sulla inserzione spontanea di una pianta di *Quercus Ilex*, L., sopra altra di Platano.

„ — ——: Di una nuova stazione italiana di *Galinsoga parviflora* ed *Elcusine indica*; e della presenza di altre piante esotiche nelle vicinanze di Verona.

„ — BRESADOLA: *Corticium Martellianum*, n. sp.

„ — BOTTINI: Appunti di biologia italiana.

„ — ARCANGELI: Sulle emergenze e spine dell' *Euryale* e sulle cladosclereidi delle *Nimfeaceae*.

„ — ——: Sulla struttura del frutto della *Cyphomandra betacea*, Sendtn.

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„ 3. TERRACCIANO: La flora delle isole Tremiti.

„ — ———— ——: La flora del Polesine.

„ — ———— ——: Le piante dei dintorni di Rovigo (cent. 1°.)

„ — KRUCH: Istologia ed istogenia del fascio conduttore nelle foglie di *Isoètes*.

„ — ——: Sulla struttura e lo sviluppo del fusto della *Dahlia imperialis*.

„ — GOIRAN: Sopra diverse forme appartenenti ai generi *Scolopendrium*, *Crocus*, *Acer*, *Ulmus*, *Linaria*.

„ — ——: Della *Malabaila Hacquetii*, Tausch. e della *Senebiera Coronopus*, Poir. nel Veronese, e della *Fragaria indica*, Andr. nel Bergamasco.

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„ — ————: Sull' *Helicodiceros muscivorus*, (L. fil.) Engler.

„ — TANFANI: Rivista delle Sileninee italiane.

„ — POLI: Alcune osservazione sul reagente di Millon.

„ — MARTELLI: Un caso di dissociazione naturale nei Licheni.

„ — ————: Sulla *Torula spongicola*, Dufour.

„ — GRILLI: Di alcuni Licheni marchigiani.

„ — ——: Su di un Lichene raro.

„ — CARUEL: Un piccolo contributo alla flora Abissina.

„ — SOMMIER: Ancora sulla *Lonicera coerulea*.

„ 4. MASSALONGO: Di due Epatiche da aggiungersi alla flora italica.

„ — GOIRAN: Sulla presenza di *Orchis provincialis*, L., sui monti Lessini Veronesi.

„ — MARTELLI: Sull' origine dei Viburni italiani.

„ — TANFANI: Sul genere *Moehringia*.

„ — ARCANGELI: Altre notizie sul *Dracunculus vulgaris*, Schott.

Malpighia (Genoa, 1890). Anno III (*continued*).

Fasc. IX.

DELPINO: Sulla impollinazione dell' *Arum Dracunculus*, L.

DE TONI: Note sulla Flora Friulana, serie terza (continued in Fasc. X–XII).

BRIZI: Contribuzione all' Epaticologia italiana.

Fasc. X–XII.

BELLI: Che cosa siano *Hieracium sabaudum*, L., e *H. sabaudum*, All., studi critici (Tav. XIV–XVI).

BACCARINI: Intorno agli elementi speciali della *Glycine sinensis* (Tav. XVII).

MATTIROLO: Sul valore sistematico della *Saussurea depressa*, Gren., nuova per la Flora Italiana.

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ARCANGELI: Sulla impollinazione del *Dracunculus vulgaris*, Sch., in risposta al Prof. F. Delpino.

ROSS: Contribuzioni alla conoscenza del periderma, I (continued in IV, Fasc. I–III).

Malpighia (*continued*).

Anno IV. Fasc. I–III.

DELPINO: Note ed osservazioni botaniche, decuria seconda (Tav. V).

1. Biologia delle Gimnosperme.
2. Pensieri ed osservazioni sulla disseminazione.
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7. Anemofilia di *Bocconia frutescens*, *Dodonaea viscosa*, *Erica scoparia*, *Mercurialis perennis*.
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9. Staurogamia presso il *Sauromatium guttatum*.
10. Symbiosi fra epatiche fogliose e rotiferi.

PAOLETTI: Nota preliminare sui movimenti delle foglie nella *Porlieria hygrometrica*.

BERLESE: La famiglia delle Lophiostomaceae, Sacc.

KRUCH: Istologia ed istogenia del fascio conduttore delle foglie di *Isoëtes* (Tav. I–IV).

CAVARA: Di una rara specie di *Brassica* dell' Appennino emiliano (Tav. VI).

Fasc. IV.

LANZA: La struttura della foglie delle Aloinee ed i suoi rapporti con la sistematica (Tav. VII).

MALLADRA: Sul valore sistematico del *Trifolium ornithopodioides*, Sm. (Tav. VIII) (continued in Fasc. V–VI).

Fasc. V–VI.

TERRACCIANO: Specie rare o critiche di Geranii italiani.

PIROTTA: Le specie italiane del Genere *Helleborus*, Adans., secondo il Dr. V. Schiffner.

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BRIZI: Note di Briologia italiana.

Fasc. VII-VIII.

BRESADOLA ED SACCARDO: Pugillus Mycetum Australiensium (Tav. IX).

DELPINO: Contribuzione alla teoria della pseudanzia (Tav. X).

MATTIROLO E BUSCALIONI: Il tegumento seminae delle Papilionacee nel Meccanismo della respirazione (Tav. XI–XVI).

BALDACCI: Nel Montenegro; cenni ed appunti intorno alla Flora di questo paese.

BOTTINI: Sulla riproduzione della *Hydromystria stolonifera*, Meyer.

BRIZI: Note di Briologia italiana, II.

BELLI: *Avena planiculmis*, Schrad., var. *β taurinensis*, Nob.

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Anno IX.

No. 1. LOJACONO: Prima nota in risposta alla rivista critica delle specie italiane dei Trifogli della sezione *Chronosemium* dei Signori Gibelli e Belli (*v.* also Nos. 3–8 and 10–12).

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No. 4. NICOTRA: Schedule speciografiche riferentesi alla flora siciliana (*continued*) (continued in Nos. 5 and 12).

„ 6. LOJACONO: Primo elenco di Licheni in Sicilia (*continued*) (continued in No. 7).

„ 9. PISTONE: Disseminazione zoofila per uccelli fitofagi (*continued*) (continued in No. 10).

Anno X.

No. 2–3. NICOTRA: Schedule speciografiche riferentisi alla flora siciliana (Saggio nono) (*concluded*).

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No. 17. DE-TONI: Osservazioni sulla tassonomia delle Bacillariee (Diatomee) seguite da un prospetto dei generi delle medesime.

„ — Algae novae: Diagnoses.

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„ — LEVI-MORENOS: Quelques idées sur l'évolution défensive des Diatomées en rapport avec la diatomophagie des animaux aquatiques (continued in Nos. 19–20).

„ 19. HARIOT: Le genre *Bulbotrichia*.

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„ — DANGEARD: Indication sur la récolte des algues inférieures: modes de culture et technique (illustrated).

„ — MAGNUS: Sulla diffusione geografica della *Sphaeroplea annulina* (Roth), Ag.

„ — LANZI: Diatomacearum naturalis et methodicae distributionis specimen.

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IV. Cenni intorno alle matrici nelle quali vive l' *Enteromorpha compressa* ed alla sua distribuzione batimetrica.

V. Frammenti algologici per l'isola di Caprera.

VI. Risposta alla nota del Sig. Rodriguez 'La costituzione mineralogica del suolo puo contribuire alla ricchezza algologica di un paese?'

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IV. Di una seconda località italiana per la *Palmella miniata*, Leibl.

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VI. La *Terpsinoè Musica*, Ehr. a S. Thomé (W. Africa).

VII. *Wildemania*, nuovo gen. di Porfiracee.

October. LAGERHEIM: *Bertholdia*, nov. nom. u. *Dictyocystis*, nov. gen.

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Fasc. 4. MESCHINELLI: La Flora dei Tufi del Monte Somma.
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Anno IX (*continued*).

Nos. 23, 24.
MATTEI: Due nuove quercie orientali.
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Anno X.

No. 2. BRIOSI: Ricerche fatte al laboratorio di Botanica crittogamica di Pavia (continued in No. 3).
„ 4. CUBONI: Rassegna crittogamica (Fungoid diseases of various plants) (continued in Nos. 5–6).
„ 5. LOJACONO: Terzo elenco briologico di Sicilia (continued in No. 6).
„ — CLERICI: Sopra una nuova pianta rivivescente (*Polypodium incanum*, Pluck.).
„ 6. CHIODI: Doppio Endocarpio in un frutto d'arancio.
„ 8. MATTEI: Note botaniche.
„ 9. PALUMBO: Teratologia Vegetale (*Fraxinus ornus*, L.).

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Vol. VII (*continued*).
HENRIQUES: Estudos phaenologicos.
Flora Lusitana exsiccata, Cent. VII and VIII.
SACCARDO ET BERLESE: Mycetes aliquot Guineenses.
Recherches histologiques sur le *Podocarpus Mannii*.

Fasc. 3.
HAUCK: Algas do Norte de Portugal.
BRESADOLA ET ROUMEGUÈRE: Nouvelles contributions à la Flore mycologique des Iles St. Thomé et du Prince.
LAGERHEIM: Ueber einen neuen phosphorescirenden *Polyporus* aus Angola.
HENRIQUES: Catalogo dos Musgos encontrados em Portugal (continued in Fasc. 4).

Fasc. 4.
HENRIQUES: Contribuiçoes para o conhecimento da Flora d'Africa. Catalogo de Plantas de Africa Portugeza.

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NADSONA: Obrazovanie krakhmala b khlorofillonosncikh klyetkakh ractenii iz organicheskikh veshchestv. (*Physiological.*) pp. 73–122.

KOSTCICHEVA: Obrazovanie i svoistva pereghnoya. pp. 123–168.

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Häft 1. ANDERSSON: Bidrag till Vesterbottens växtgeografi.

„ — BERG: Kritik öfver några växtformer, beskrifna af H. Brehm.

„ — ELFVING: Kulturförsök med *Penicillium glaucum.*

„ — HEDLUND: Några iakttagelser rörande *Ranunculus* (*Batrachium*) *paucistamineus*, Tausch., Tullb.

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„ — KIHLMAN: Ett besök på Solovetska öarne.

„ — KELLGREN: Några växtfysiognomiska anteckningar.

Botaniska Notiser (*continued*).

Häft 1. JUEL: Några mykologiska notiser.
„ — SERNANDER: Om förekomsten af subfossila stubbar på svenska insjöars botten.
„ — WILLE: Yderwgere om regnopfangende Planter (continued in Hft. 2).
„ 2. ANDERSSON: Bidrag till Södermanlands *Hieracium*-flora.
„ — ARNELL: Om de skandinaviska *Thyidia tamariscina*.
„ — BRENNER: *Glyceria distans* i Finland.
„ — FRIES: Om *Beckmannia erucaeformis* (L.), Host.
„ — GREVILLIUS: Om en fascierad form af *Sideritis lanata*, L.
„ — JÄDERHOLM: Om *Salix Lapponum* × *repens*, Wimmer.
„ — MURBECK: *Bromus patulus*, Auct. suec., *Luzula pallescens*, Auct.
„ 3. ARNELL: Om några *Jungermania ventricosa* närstående lefvermossarter.
„ — JUNGNER: Ett fall af fasciation hos *Berberis vulgaris*, L.
„ — KJELLGREN: Studier öfver Ombergsflorans papilionaceer.
„ — LINDVALL: Om några enskilda herbarier i norder 1772.
„ — LUNDSTRÖM: Slutord i frågan om de regnuppfångande växterna.
„ — SERNANDER: Några bidrag till den norrländska kalktuffloran.
„ — SKÅRMAN: Om *Salix hastata* × *repens*, n. hyb.
„ — STARBÄCK: Några mykologiska notiser.
„ 4. BERG: Lichenologiska anteckningar.
„ — SAMZELIUS: Vegetationsiakttagelser inom Pajala socken.
„ 5. MELANDER: Anteckningar till Vesterbottens flora.
„ — MURBECK: Studier öfver kritiska kärlväxtformer, I.
„ 6. FRIES: Shödda bidrag till kännedom om Skandinaviens barrträd.
„ — JOHANSSON: Om fanerogamvegetationen kring Visby vintern, 1889-90.
„ — LAGERHEIM: Mykologiska bidrag. VII—Ueber *Aecidium Astragali*, Erikss.
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„ 8. NATHORST: Om förekomsten of *Dictyophyllum Nilssoni*, Brongn., sp. i Kinas kolförande bildningar.
„ — KINDBERG: Bidrag till kännedomen om Canada-områdets Mossflora.

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Tome XIX. Cuaderno 1.

RODRIGUEZ Y FEMENIAS: Datos algologicos. (Lám. II.)

———: Herborization en Panticosa (Julio y Agosto de 1889).

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Tome XXIII.

No. 1. ETTINGHAUSEN ET KRASAN: Observation sur l'atavisme des plantes.

„ — CHODAT: Classification des Polygalacées.

„ 2. SCHWEINFURTH: Rapports entre la flore de l'Arabie Heureuse et celle de l'Égypte. Observations par M. De Candolle.

„ — D'ESPINE: Recherches expérimentales sur le bacille diphthéritique.

„ 3. FOREL: Recommandations en vue de l'étude systématique de la flore du rivage du Léman.

„ 4. MÜLLER: Travaux sur les Lichens.

„ — DE CANDOLLE: Sur les causes de l'orientation des matières d'origine protoplasmique dans la caryocinèse.

„ 6. CHODAT: Transformation des grains de chlorophylle en leucites amylogènes dans *Calanthe Sieboldtii.*

„ 11. FRÜH: Étude de la tourbe.

„ — TSCHIRCH: Contributions à l'étude physiologique et biologique des graines.

„ — FISCHER: La *Trichocoma paradoxa.*

„ — CHODAT: Systématiques des Cramériacées.

„ — ———: Production d'amidon dans les pseudobulbes du *Calanthe bulbosa.*

„ — ———: Malpighiacées du Paraguay.

„ — SCHINZ: Synonymie du *Potamogeton javanicum.*

„ — AMANN: Mousses nouvelles de Davos.

„ — ———: Polarisation dans les membranes des mousses.

„ — MICHELI: Fertilité des fleurs de *Montbretia crocosmiaeflora.*

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SCHRÖTER: Sul clima delle Alpi e sulla sua influenza sulla vegetazione alpina. p. 22.

CHODAT: Identité du *Puccinia Scirpi*, DC., avec *Aecidium Nymphoides.* p. 43.

———: Sur la fleur du *Sempervivum.* p. 43.

RHINER: Sur l'exploration botanique des Cantons primitifs depuis 1884. p. 44.

FISCHER: Sur quelques Sclerotium. p. 45.

Atti della Società Elvetica delle Scienze Naturali adunata in Lugano (*continued*).

CAVARA: Scoperta sull' Apennino settentrionale della *Brassica Robertiana*, Gay. p. 45.

——— : Caso di simbiosi tra funghi parassiti. p. 46.

CALLONI: Appunti sulla famiglia delle Berberidacee. p. 47.

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„ — SQUINABOL: Di un tipo paleocenico di Quercinea ritravato nel miocene inferiore di S. Giustina, e di alcune altre Piante rare della medesima giacitura (c. tav.).

„ — ———— : Alghe e Pseudoalghe italiani.

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No. 100. FAVRAT: Note sur quatre hybrides nouveaux, &c.

„ — BARBEY: Diagnose du *Cephalaria salicifolia*.

„ — FAVRAT: Floraison d'un certain nombre de plantes en décembre 1888 et Janvier 1889.

„ 101. BLONAY: Sur une nouvelle méthode forestière dite du contrôle.

„ — FAVRAT: Note sur quelques plantes trouvées en 1889 et sur l'étang de Sauvabelin.

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CRAMER: Ueber die verticilloiten Siphoneen, besonders *Neomeris* u. *Bornetella* (with 4 Plates).

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Mémoires de la Société de Physique et d'Histoire naturelle de Genève. (Geneva, 1889–90.) Tome XXX. 2e Partie.

MICHELI: Contributions à la flore du Paraguay. Supplément II. Légumineuses (4 Plates).

CHODAT: Contributions à la flore du Paraguay. Supplément III. Polygalacées (5 Plates).

BRUN ET TEMPÈRE: Diatomées fossiles du Japon (9 Plates).

Mittheilungen der Thurgauischen Naturforschenden Gesellschaft. (Frauenfeld, 1890.) Heft 9.

BOLTSHAMER: Eine Krankheit des Weizens (m. Taf.).

NAGELI U. WEHRLI: Beitrag zu einer Flora des Kantons Thurgau.

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Verhandlungen der Naturforschenden Gesellschaft in Basel. (Bâle, 1890.) Bd. IX. Heft 1.

GUTZWILLER: Beitrag zur Kenntniss der Tertiärbildungen der Umgebung von Basel.

ERRATUM.

p. 175, bottom line, *for* 5–8, *read* 10–13.

A Monograph of the British Gastromycetes.

BY

GEORGE MASSEE.

With Plates, I, II, III, IV.

MORPHOLOGY.

THE group of fungi known as the Basidiomycetes, characterised by the spores being borne on terminal clavate cells or basidia, arranged side by side and forming a continuous spore-bearing surface or hymenium, is divided into two sub-groups, the Hymenomycetes and the Gastromycetes, the former distinguished by having the hymenium exposed before its complete differentiation, whereas in the latter the hymenium is concealed until the spores are mature and ready for dispersion.

The above expresses the salient features of the divisions from the systematist's point of view, whose diagnoses almost invariably convey the erroneous impression that the various groups under consideration, although related to each other, are respectively defined by the characters given, whereas in nature, as apart from books, such morphologically isolated groups are rare; the most general experience being that the diagnosis only includes in reality the so-called typical representatives of the group, and as we depart from the central nucleus of typical species, the characteristic features become less and less pronounced and mixed with other characters foreign to the typical forms, which by degrees predominate,

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and in turn constitute the leading structural features of a new group. These numerous transitional species which hover round each group are respectively the sheet-anchor of the biologist and evolutionist, and the bane of the old-school systematist.

The broad features of development in the two groups named above may be characterised as follows. In the Hymenomycetes the simplest genera, as *Corticium* and *Peniophora,* consist of a broadly effused undifferentiated sporophore attached by the whole of its under surface to the substratum, the upper or free surface forming a continuous even hymenium. From this primitive condition the modifications of the hymenial surface all tend towards one idea, that of exposing the greatest possible area of spore-bearing surface in the least possible space, and evolving in the following ascending order: Thelephoreae, hymenium even, plane; Clavarieae, hymenium even, sporophore club-shaped or variously branched; Hydneae, hymenium broken up into more or less flattened teeth or spines; Polyporeae, hymenium honeycombed or consisting of closely-packed tubes lined with basidia; Agaricineae, hymenium spread over thin plates or gills arranged side by side and radiating from a central point.

The progressive differentiation of the sporophore persistently aims at one object, that of concealing the hymenium until the spores are mature, a statement which is not in harmony with the general conception that in the present group the hymenium is from the first exposed. In the Thelephoreae, Clavarieae, and Hydneae the hymenium is exposed from the earliest stage, whereas in the Polyporeae and the Agaricineae the hymenium in the higher forms is completely differentiated while yet concealed by a structure known as the veil, which in many species is only ruptured by the expansion of the pileus when the spores are mature. The idea of concealing the hymenium from the light is equally apparent in the various orders enumerated, excepting the Clavarieae. In the Thelephoreae, as already stated, the simplest genera, *Corticium, Coniophora,* and *Peniophora,* have the hymenium covering the whole of the uppermost or free surface of the sporophore, and consequently

from the earliest period of development exposed to the light; whereas in the genera *Stereum* and *Thelephora* a portion of the hymenophore becomes free from the substratum and bends over, thus turning the hymenium away from the light, and by a series of transitions described in detail elsewhere[1], we find the higher species of the two last-named genera assuming umbrella-shaped forms with a central stem and inferior hymenium, but not at any period covered by a veil. In the Agaricineae we meet with the same sequence of evolution; in such low forms as *Cantharellus retirugis*, Fr., and *Agaricus* (*Pleurotus*) *hypnophilus*, P., the plants are fixed to the substratum by the pileus with the hymenium uppermost, and may be compared to a *Corticium* with the hymenium imperfectly broken up into gills, whereas such species as *Agaricus* (*Pholiota*) *praecox*, P., and *Agaricus* (*Amanita*) *muscarius*, L., the hymenophore is supported on a stem with the hymenium on the underside, and concealed by a veil until the spores are mature. Finally, the same sequence of sporophore evolution may be observed in large genera, as *Stereum*, *Polyporus*, and *Agaricus*. There is a marked absence of any special arrangement of the sporophore for spore-dissemination.

In the Gastromycetes, with the exception of the species constituting the genus *Gauteira*, the hymenium is completely concealed by a continuous wall or peridium until the spores are mature. It has been shown that in the genera *Crucibulum*[2], *Phallus*[3], *Sphaerobolus*[4], and *Matula*[5], the sporophore originates from the vegetative mycelium as a minute undifferentiated weft of hyphae, and as suggested by De Bary[6], this mode of origin is probably common to all. No traces of sexual organs have been observed. The peculiar form of coalescence between two hyphal cells

[1] G. Massee, A Monograph of the Thelephoreae; Linn. Soc. Journ., vol. xxv, p. 107.

[2] De Bary, Fungi, &c., Engl. Ed. p. 319.

[3] De Bary, l. c. p. 322.

[4] Ed. Fischer, Zur Entwicklungsgesch. d. Gastromyceten, in Bot. Ztg. 1884 (Sphaerobolus, Mitremyces).

[5] G. Massee, On the type of a new order of Fungi; Journ. Roy. Micr. Soc., 1888, p. 175.

[6] l. c. p. 313.

first described by Hoffmann [1] under the name of clamp-connections, is not uncommon, and originates as follows. A slender lateral branch springs close to a transverse septum separating two superposed cells, and after growing for some time its tip comes in contact with the wall of the adjoining cell just beyond the septum, absorption of the walls takes place at the point of contact, and thus at first an open communication is established by means of the lateral branch between the two adjoining cells; at an early period this channel of communication is usually interrupted by the appearance of a septum at the point of origin of the lateral branch, and a second septum is in some instances formed at the point of contact with the second cell. The lateral branch is usually closely adpressed to the hypha from which it springs, but sometimes becomes arched and free from the hypha between the two points of attachment (Fig. 36). In the genus *Tulostoma*, in addition to clamp-connections, the hyphae are often swollen at the nodes, due to continued increase in diameter of the transverse septa (Fig. 33, *b*). No explanation has been offered as to the meaning of these peculiar structures, which occur in most, if not all, genera belonging to the Basidiomycetes having the hypha furnished with transverse septa. Similar structures are characteristic of the genus *Zygodesmus*, which up to the present has been considered as belonging to the *Hyphomycetes*, although, as I have pointed out elsewhere, it is impossible to separate by other than traditional ideas the present genus from *Thelephora*.

The differentiation of hyphae is well seen in the group under consideration. In the gleba of the Lycoperdeae at a very early period, two sets of hyphae are present: one thin-walled, colourless, septate, and rich in protoplasm, give origin to the trama and elements of the hymenium, and usually disappear entirely after the formation of the spores (Fig. 73); the second type consists of long, thick-walled aseptate or sparsely septate, often coloured hyphae, which are persistent, and form the capillitium (Figs. 63 and 74). The latter are

[1] Bot. Ztg. 1885, p. 156.

branches of the hyphae forming the hymenium. In the Phalloideae and the Lycoperdeae different zones of the substance of the external protective layer, known as the volva in the former and the peridium in the latter, become remarkably differentiated, which results in the splitting-up of the originally homogeneous coat into two or more distinct layers. This may be due to the gelification of a middle layer, as described by De Bary[1] in the genus *Geaster*; or to its disintegration into a friable powder as in *Calostoma*[2]. The structure of the peridium varies considerably in the different orders, and as would be expected, is least differentiated in the subterranean Hymenogastreae, where it consists of a thick comparatively homogeneous, indehiscent wall, enclosing the hymenium-bearing portion, collectively known as the gleba. The expression subterranean, as applied to the members of the Hymenogastreae, means that the plants remain underground after the spores are mature. In the Phalloideae and some genera belonging to the Lycoperdeae, as *Geaster*, *Tulostoma*, *Battarrea*, etc., differentiation of the gleba up to the formation and ripening of the spores takes place while the sporophore is below the surface of the ground, from which it emerges for the sole purpose of spore dissemination, and the leading idea in the progressive evolution of the sporophore is that of accomplishing the above-mentioned function in the most effectual manner, which is attained in the Phalloideae, where the very minute spores, mixed with mucus resulting from the disintegration of the constituents of the hymenium, form a semi-liquid, strong-smelling mass, greedily sought after and devoured by flies, by whose agency the spores are dispersed. The genera *Scleroderma* and *Polysaccum* form a transition from the subterranean forms to those that emerge above ground when mature, and in these genera the peridium is structurally but little in advance of that of the Hymenogastreae.

There is much less variety in the arrangement of the

[1] l. c. p. 316.

[2] G. Massee, A Monograph of the genus *Calostoma*, Desv. (*Mitremyces*, Nees); Ann. Bot., vol. ii. pp. 25-45, Pl. III.

hymenial surface in the present group than in the Hymenomycetes, in fact, so far as relates to the earliest condition, it may be said that there is but one plan. The first sign of differentiation observable in the young gleba is the appearance of numerous minute rifts in the hitherto homogeneous weft of hyphae. These rifts increase in size with the growth of the sporophore, and eventually form a complicated labyrinth of sinuous cavities. The walls separating the cavities consist of branched septate hyphae which in the middle portion usually run more or less parallel to the surface of the walls and constitute the trama. The free surfaces of the walls enclosing the cavities become converted into the hymenial layer, the basidia being terminal branches of the hyphae of the trama (Fig. 54). The walls of the gleba are at first always continuous with the inner surface of the peridium, and in the Hymenogastreae and the Sclerodermeae are persistent, as they are also to some extent in the Nidularieae, whereas in the Lycoperdeae and the Phalloideae, the whole of the trama and hymenial layer disappear after the formation of the spores. Further details relating to the structure of the gleba will be given under the respective orders. The basidia are much more variable in form, and the number of spores by no means so constant as in the allied Hymenomycetes. In the Hymenogastreae the number of spores borne on a basidium varies from one to four, two being the most usual number, and it is by no means unusual to meet with bisporous and tetrasporous basidia in the same hymenium. In the Phalloideae the very minute spores vary from four to eight on different basidia. According to De Bary[1] the large clavate basidia of *Geaster hygrometricus* produce eight sessile spores. In the genera *Bovista* and *Lycoperdon* the basidia are tetrasporous, the spores being supported on very long sterigmata, which in most species break off close to the basidium and remain permanently attached to the spores, which explains the term 'spores stipitate,' sometimes used by systematists (Fig. 62). In all the examples hitherto

[1] l. c. p. 63.

enumerated the spores spring from the apex of the basidia, but in the genus *Tulostoma* the club-shaped or semi-cylindrical basidia bear four spores placed at some distance from each other on the lateral wall (Fig. 33, *a*). Contrary to what would have been expected, the largest, most highly ornamented and deepest coloured spores are met with in the least differentiated orders, the Hymenogastreae and the Sclerodermeae, and as we pass upwards through the Lycoperdeae to the Phalloideae the spores become smaller, and in the last-named order are always very minute, smooth, and colourless or nearly so, the green tinge being mostly due to the dense mass of olive-green mucus in which they are imbedded in all known species. To the above general statement there are, as would be expected, some exceptions; in *Podaxon*, a genus belonging to the Lycoperdeae, the spores are large and brightly coloured, but smooth; in some species of *Cyathus* again the spores are large, but smooth and colourless. All spores are colourless during the immature state, the colouring matter appearing just before maturity. The wall of a ripe spore consists in all cases of at least two distinct layers, the endosporium and the exosporium: the first always remains smooth, the ornamentation of the surface being due to local shrinkage or contraction of the exosporium, the uncontracted portions assuming the form of spines, warts, sinuous lines, or form a more or less regular polygonal network of ridges (Figs. 14 and 70, *a*). If such ornamented spores are treated for some time with a dilute solution of potassic hydrate, the contracted portions expand, and the exosporium eventually appears as a thick, even, colourless membrane surrounding the endosporium. The presence of a nucleus can be in many cases demonstrated in young spores. The 'nuclei' of systematists consist of oil globules or vacuoles.

As already stated, two leading features stand out prominent in the evolution of the Hymenomycetes; the conversion of the primitive even hymenial surface into gills, thereby increasing the spore-bearing area, and secondly, the gradual concealment of the hymenium until the spores are mature.

In the Gastromycetes these two conditions are present in the lowest forms, and persist throughout the group, the very varied forms presented by the different orders being the outcome of modifications of the sporophore in connection with spore-dissemination. The most prominent types will be described later on.

It is interesting to note that so long as spore-dissemination depends on physical causes, as in the Hymenogastreae, Sclerodermeae, Lycoperdineae, and Nidularieae, the plants are devoid of bright colours, dirty ochre being the most general tint, whereas in the Phalloideae where the dispersion of the spores depends mainly on the visits of insects, more especially dipterous forms, food is provided in the form of mucus formed by the diffluent hyphae of the hymenial layer, its whereabouts being indicated as in Phanerogams by the usual advertisements, smell and colour, the former being in most cases very pronounced, the latter usually some shade of red, varying from deep rose to orange-vermilion. It must not be inferred from the above statement that scent or colour perform the same function for all fungi possessing them. The brilliant colours and varied scents of many of the Hymenomycetes are so far as is known of no direct service to their possessors, and certainly not in connection with spore-dissemination.

Hymenogastreae. The most pronounced features of the present group are, (1) subterranean habit, (2) total absence of capillitium, (3) gleba not becoming resolved into a powdery mass when mature, (4) indehiscent peridium.

The usually copious mycelium often forms fleecy masses spreading amongst vegetable humus at a distance of one or two inches below the surface, and in the genera *Melanogaster* and *Rhizopogon* more especially forms irregularly branched or anastomosing cord-like strands, which give origin to sporophores at various points; hence it is not unusual to meet with clusters of plants of different sizes attached to the spreading mycelium, as in *Ithyphallus impudicus*. Most species grow under trees, and several have only been met with in close proximity to certain kinds of trees, which suggests the proba-

bility of commensalism, as already shown by Rees and Fisch[1] to exist between the species of *Elaphomyces* and fir-trees. The sporophore originates from the mycelium as a minute spherical weft of undifferentiated hyphae, in which air-spaces are observable at a very early period. Somewhat later the gleba or central portion of the weft becomes broken up into a large number of irregular sinuous cavities, at first traversed by slender hyphae from wall to wall, which eventually disappear. The septa separating the cavities undergo further differentiation into a trama, with the hyphae running more or less parallel to the walls, and a hymenium consisting of closely-packed terminal cells, originating from the hyphae of the trama, arranged perpendicularly to the surface, which in all genera, except *Melanogaster*, forms an even wall lining the cavities. In the last-named genus the fertile cells of the hymenium are of various lengths, and at first fill the cavities. The basidia are clavate except in the genus *Hymenogaster*, where they are generally cylindrical, not thicker than the sterile cells, and when fully developed project considerably beyond the level of the hymenium; Tulasne has figured a portion of the hymenium of *Hymenogaster decorus*[2], where, in addition to the normal type of basidia, two slender branches of the trama have pushed beyond the hymenial surface, and without undergoing the slightest morphological change, each supports a perfectly developed spore at its apex. It has become the fashion of late to consider spores produced on hyphae that do not present the structure characteristic of basidia, as gonidia, but in the genus under consideration, as indeed throughout the group, great variability is observable in the elements of the hymenium, and the distinction between so-called gonidia and basidiospores becomes meaningless, and only proves the group to represent the starting-point of the Gastromycetes. Numerous instances of similar instability in the spore-bearing threads of the hymenium are present in such genera as *Pistillaria*, *Aleurodiscus*, and *Corticium* amongst the

[1] Uhlworm and Haenlein's Bibl. Bot., Heft VII. 24 pp. and 1 Pl. (1887).

[2] Fungi Hypogaei, t. x. Fig IX. 2.

Hymenomycetes. In the Hymenogastreae the basidia are most frequently bisporous, although it is not unusual to meet with basidia bearing one, two, or three spores respectively in the same hymenium, in addition to the gonidia-form, as in *Hymenogaster tener*.

In typical basidia the sterigmata or outgrowths which support the spores are very slender cylindrical hair-like bodies, but in the present group are usually much stouter, and suggest the idea, in the bisporous forms, of the basidia being furcate at the apex (Figs. 1 *c* and 8 *a*). When fully formed, the sterigmata become inflated in a spherical manner at the apex, into these inflated terminal portions the protoplasm from the basidium passes, after which a transverse septum is always formed across the sterigma immediately below the terminal inflated portion, the latter eventually becoming differentiated into a spore which falls away from its support when ripe. It is rather remarkable that the present group, in spite of its general low standard of development, should possess, almost invariably, such large, coloured, and highly ornamented spores, varying in form from spherical to elliptical or lemon-shaped, the most usual shape, and furnished with warts, spines, or raised lines forming a network of polygonal figures. In *Melanogaster* the spores are comparatively small and smooth (Fig. 5 *b*). The colour varies in different species from very pale olive through various shades of brown to almost black and opaque. In many species the outer layer of the episporium is colourless and loosely invests the spore like a sac, which suggests the idea of a single spore contained in an ascus; this peculiar structure is best studied in *Hymenogaster tener*, where the outer hyaline coat is twice the size of the coloured spore in its interior (Fig. 1 *a*–1 *c*). After the spores have become free the external hyaline membrane contracts, and appears as a thin rugged layer. The spores are invariably globose, smooth, and colourless at first, whatever structure and colour they may eventually present. The hyphae forming the peripheral portion of the sporophore undergo but little differentiation and form the peridium, which is often thickest

at the base, corresponding to the point of attachment of the sporophore with the mycelium or vegetative portion of the plant. The thickened portion is known as the sterile basal stratum, and may form a spurious stem-like structure, as in *Octaviania asterosperma*, or project into the interior, in the form of an imperfect columella, as in most species of *Hymenogaster*.

Sclerodermeae. The species belonging to the present order occupy an intermediate position between the Hymenogastreae and the Lycoperdeae, differing from the former in not being subterranean, and from the latter in the absence of a capillitium and the indehiscent peridium. As in the Hymenogastreae, the peridium is thick, usually warted or rugulose externally, and but little differentiated, the trama springing from every part of its inner surface. Sorokin has shown[1] that in *Scleroderma verrucosum* the hymenial elements of each cavity of the gleba originate from the branching of a single hypha, which enters the cavity at an early period of development. In *Polysaccum* the cavities of the gleba are comparatively large and uniform in shape, being more or less polygonal in section. The walls of the trama are bright yellow in most species. In this genus the peridium appears to be completely formed at a considerable distance underground, as some species have a stout stem-like base from eight to ten inches long, and completely buried in the ground, the peridium alone appearing at the surface. From what is known in other instances, the stem probably remains rudimentary until the spores are mature, when it elongates for the purpose of raising the peridium to the surface, thereby facilitating the dispersion of the spores.

Nidularieae. The first indication of differentiation presented by the young sporophore consists in the gelification of a zone of the homogeneous weft of hyphae which commences near the base and extends upwards, parallel to, and at some distance within, the periphery, the external portion

[1] Sorokin, Ann. Sci. Nat., Sér 6, vol. iii p 30.

persisting as the peridium, which in *Cyathus* becomes further differentiated into three layers, in *Crucibulum* into two, and in *Nidularia* remains homogeneous. In *Crucibulum* the apical portion of the external layer of the peridium ceases to grow at an early stage, while the inner layer keeps pace with the expansion of the sporophore and forms a white membrane or epiphragm which eventually falls away, leaving a wide opening. Following the formation of the peridium, and while the sporophore is yet increasing in size, gelification of the tissue extends towards the centre, certain isolated portions of the primitive tissue remaining, which constitute the primordia or starting-points of the peridiola, which remain at the bottom of the peridium after the disappearance of the mucilage resulting from disintegration of the surrounding tissue. When mature, the species of *Cyathus* and *Crucibulum* resemble small inverted bells containing minute lentil-shaped bodies, each attached to the basal portion of the peridium by a more or less elongated slender cord. These lentil-shaped bodies, considered by the earlier observers as seeds, are peridiola, homologous with the closed cavities of the gleba in other Gastromycetes, their isolation being due to the gelification and total disappearance of the central portions of the tramal plates. When the peridiola are fully developed a section reveals a central cavity lined with hymenial elements consisting of bisporous or tetrasporous basidia and paraphyses; large fusiform cystidia are also present in *Nidularia pisiformis* (Fig. 37, *a*). The cord or funiculus by which the peridiolum is attached to the inner wall of the peridium presents a complex structure, first clearly described by Tulasne[1]. In *Cyathus striatus* the funiculus varies from 2–3 mm. in length, and is cylindrical with a constriction in the centre. The distal end which is attached to the peridium, as also the thin central isthmus-like portion, are solid, and consist of slender, thick-walled hyphae. The thick portion above the central constriction is hollow, its walls passing into the tissue of the peridiolum at a depressed point on the centre

[1] Ann. Sci. Nat., Sér. 3, vol. i. p. 14.

of the face pointing obliquely towards the base of the peridium. The hollow portion of the funiculus is about 1 mm. in length, and contains a slender coiled cord, which measures when opened out from 3–4 cm., but when moist can be stretched to 8 cm. without breaking (Fig. 48, *a*). One end of this coil is attached to the peridiolum, the other to the thin central portion of the funiculus. In *Crucibulum* the funiculus is less complicated in structure, the hollow portion enclosing the coil undergoes gelification at an early period, and the coil, which resembles a small protuberance in the centre of the umbilical depression of the peridiolum, is enclosed in the resulting mucilage. In different species intermediate forms of development of the funiculus, as would be expected, are met with. The object of this complex arrangement is not understood. Brefeld suggests the possibility of its being an aid to spore dispersion, and scarcely any other idea seems to suggest itself. The genus *Sphaerobolus* is characterised by the complex peridium enclosing a single spherical peridiolum or sporangiolum. The following is from Fischer's masterly account of *Sphaerobolus stellatus*[1]. The sporophore, which is about 2 mm. in diameter, consists at first of a homogeneous weft of hyphae. The peridium agrees with the exoperidium in *Geaster* in general structure, and consists of four layers (Fig. 55); the outermost or mycelial layer (Fig. 55, *m*) is composed of loosely woven hyphae, and passes inwards into the pseudo-parenchymatous layer, consisting of intricately interwoven hyphae, presenting the appearance of parenchymatous tissue in section (Fig. 55, *p*), and is in turn lined by the fibrillose split-layer (Fig. 55, *p*). The innermost or collenchyma-layer consists for the most part of rather large cells, which form a palisade-tissue with their long axes at right angles to the surface of the peridium (Fig. 55, *c*). When mature the peridium splits at the apex in a stellate manner caused by the extension of the collenchyma-layer, which continues to grow at its peripheral surface after the peridium is ruptured. The positive

[1] Bot. Ztg. 1884. p. 448.

tension set up by the continued growth of the collenchyma-layer eventually causes it to tear away from the external portion of the peridium, and carrying the split-layer along with it, becomes extended from the stellate opening as in *Geaster fornicatus*, remaining attached at the tips of the rays only (Fig. 55, *b*). When the extension takes place slowly the spherical gleba remains seated on the collenchyma-layer, but in most instances the process occurs suddenly, and the gleba is shot to a distance of more than a millimetre, and being viscid, adheres to whatever it comes in contact with (Fig. 55, *b*, *s*). The gleba, which externally resembles a spherical peridiolum, has been shown by Fischer to consist of several chambers separated by thin tramal plates and enclosed in a thin felt of hyphae, which may be considered as homologous with the endoperidium in *Geaster*. The basidia are clavate and bear from 4–7 smooth, elliptic, colourless spores, which at maturity are involved in mucus due to gelification of the hyphae forming the gleba, including the imperfect endoperidium. A few hyphal cells, especially those situated near the periphery, do not undergo disintegration but remain, and become converted into gonidia or gemmae, capable of germination. Fischer states that, when the ejected gleba is placed under conditions favourable for germination, within a day or two its entire surface is covered with germ-tubes, which radiate in all directions, forming a mycelium from which sporophores spring within a few months. These germ-tubes can be seen to originate from the above-mentioned gonidia, and not from the basidiospores, which rarely germinate, and as a rule undergo disintegration in a manner similar to the hyphae of the gleba. Nothing is known respecting the development of *Thelobolus*, which in size, habit, and general appearance, resembles *Sphaerobolus*; the basidia and spores in the two are indistinguishable.

Lycoperdaceae. The characteristic morphological feature of this order is the constant presence of a capillitium consisting of simple or branched, thick-walled, usually coloured hyphae, which remain mixed with the spores in the peridium as a dry floccose mass after the deliquescence of the tramal and

hymenial elements. The threads forming the capillitium are modified branches originating from the thin-walled hyphae of the trama or the peridium, and are usually aseptate or with only an occasional septum. The statement made by De Bary that 'the threads in *Bovista* have no transverse walls[1],' is only true of some few species, as in several South American plants belonging to this genus septa are constantly present.

It is generally supposed that the capillitium exercises some function in connection with spore-dissemination; but if so the exact way in which it acts is as yet unknown. The threads do not possess any marked hygroscopic property. The statement by De Bary, that thickened walls of the capillitium in *L. bovista* are furnished with pits[2], I have not been able to verify. In *Battarrea phalloides* a few of the threads contain well-developed spiral or annular thickenings in their interior (Fig. 29, *b*). In *Bovista* and *Lycoperdon* the peridium consists eventually of two distinct layers. In the last-named genus the outer layer, consisting of large thin-walled cells, soon fails to keep pace with the growth of the inner layer, and is consequently broken up into mealy granules. In most species these granules continue to grow at the base, and owing to the expansion of the inner layer of the peridium become separated from each other, eventually assuming the form of pyramids or spines which are frequently curved, and often split in a fibrous manner at the base and become rigid owing to partial disintegration of the walls. In many species the large spines are surrounded by a ring of small warts which persist after the former have fallen away (Fig. 32). In *Bovista* the outer layer of the peridium is continuous, but owing to early gelification of the walls, forms a friable crust, which breaks away in patches. In both genera the inner layer consists of interwoven hyphae and is persistent until the spores are mature, when disintegration takes place at the apex, and an opening is formed for the escape of the spores.

[1] l. c. p. 314. [2] l. c. p. 314.

The genera *Bovista* and *Lycoperdon* are very closely related, the only point of difference being that in the latter there is a sterile porous, basal stratum, which may be considered as a sterile portion of the gleba, and in some species is continued downwards as a more or less elongated stem-like base. In *Bovista* there is no sterile basal stratum, hence the species are invariably sessile. Intermediate stages connect the two genera, which might with advantage be united into one. In *Geaster* the peridium is more highly differentiated, and is described as follows by De Bary[1]: '*G. hygrometricus* is up to the period of perfect maturity a roundish body, which may be of the size of a hazel-nut, and remains beneath the surface of the ground. Six layers may be distinguished in the peridium in a vertical longitudinal section a short time before the compound sporophore is mature. The outermost layer is of a brownish colour, flaky and fibrous, and is continued on one side into the mycelial strands which spread through the soil, and on the other passes into the second layer; a thick stout brown membrane entirely covering the compound sporophore. This is followed towards the inside by a white layer, which is more largely developed at the base of the compound sporophore than elsewhere, and is immediately continuous at that spot with the inner peridium and the gleba. Both of these last-mentioned layers are formed of stout closely-woven hyphae running in the direction of the surface, and may be combined under the name of the fibrillose layer The inner of the two is lined on the inside by the collenchyma-layer, except where its basal portion passes into the gleba. This layer is cartilaginously gelatinous and consists of hyphal branches of uniform height connected together without interstices, which are placed palisade-like vertically to the surface and are bent as they spring from the hyphae of the fibrillose layer. The strongly thickened stratified walls of the cells of this layer have great capacity for swelling. Inwards from the collenchyma is a white layer, the innermost region of which is

[1] l. c. p. 316.

the inner peridium, while the outer, which may be called the split-layer, consists of soft, loosely-woven hyphae, which pass at many points into the inner peridium. When the fungus is quite matured, the outer peridium, through the influence of moisture and the swelling of the collenchyma-layer, bursts outwards from the apex in a stellate manner, forming several lobes which turn back, so that the upper surface which is covered by the collenchyma becomes convex. The split-layer is by this means so torn to pieces that its constituent parts remain hanging as perishable flakes, some to the collenchyma, some to the inner peridium. It is known that the collenchyma-layer retains its hygroscopic qualities a long time, and the outer peridium remains a long time lying on the soil, stellate in shape, spreading out its rays in moist weather and bending them inwards in dry. The flaky investment of the outer peridium is often more strongly developed in *Geaster fimbricatus* and *G. fornicatus* than in *G. hygrometricus*; and in *G. fornicatus* it is composed of the finest of hyphae; it tears away from the fibrillose layer when the peridium is ruptured and lies on the ground beneath the peridium as an open empty sac. The extremities of the lobes remain for the time firmly united to the margin of this sac, and as the collenchyma-layer expands greatly, the star formed by it and the fibrillose layer, especially in *G. fornicatus*, becomes convex upwards, and carries the inner peridium on the apex of the convexity' (Fig. 42). In many species of *Geaster* there is a distinct columella, often club-shaped and extending to half the height of the inner peridium. From this columella the threads of the dense capillitium radiate to all points of the inner peridium to which they are attached (Fig. 27).

It is more than probable that the species included in the exotic genus *Cycloderma* described by Klotzsch[1] are merely species of *Geaster* that have been collected before the expansion of the peridium. The two are identical in structure. Nothing is known respecting the earliest stage of development

[1] Linnaea, VII. p. 203.

in *Battarrea*. In *B. Steveni* De Bary has shown[1] that the whole course of development up to the maturing of the spores is passed while still enclosed in a volva as in the *Phalloideae*, when the volva is ruptured by elongation of the stem, which is the homologue of the receptaculum in *Ithyphallus* and *Mutinus*, a portion of the volva being usually carried up on the surface of the circular peridium, which is more or less crescent-shaped in section. Finally the peridium splits along the margin, the upper portion falling away and leaving the spores exposed on the lower persistent part from which they are soon removed by wind or rain. The hyphae with spiral or annular thickenings inside, forming the scanty capillitium, have been already alluded to. Whether these hyphae play any part in bringing about the dehiscence of the peridium is not known. Schröter, who has investigated the development of *Tulostoma*[2], states that the whole differentiation of the gleba takes place underground. When the spores are mature the short stem-like base, which consists of a central cylinder surrounded by a sheath-like continuation of the peridium, commences to elongate. This elongation is entirely due to increase in length of the central portion, the sheath being ruptured transversely, one portion remaining sheathing the base of the stem, the other forming an abrupt termination of the peridium round the apex (Fig. 34). The peridium is not separated into two layers. The peculiar basidia and septate threads of the capillitium have been already described.

Phalloideae. The three British representatives of the present order illustrate the two extremes of sporophore-differentiation, which in the present group reaches its maximum of development, in fact the various genera seem to vie with each other in their attempts to produce, at any cost, the most perfect arrangement for spore-diffusion, which in many instances has resulted in very grotesque and quaint-looking structures. It has been already stated that in the present order the spores are disseminated by insect agency, and as in the Orchideae, in

[1] l. c. p. 317.

[2] Schröter, Entw. v. Tulostoma; Cohn's Beitr. II. p. 65.

connection with fertilisation, we have extreme specialisation, and consequently a devotion of far more than a due proportion of the energy possessed in the elaboration of one factor of the organism, resulting in the production of numerous unimportant, or so-called specific characters, but detrimental to the evolution of the group in the broader sense, which may be looked upon as sacrificing the future for a momentary flourish. The Phalloideae at present stand at the head of the Gastromycetes, and owing to the loss of balance in their organisation are likely to remain so, any further marked modifications being more likely to emanate from the lower orders, as the Lycoperdeae, or the Hymenogastreae, where the energy possessed is more equally divided between the vegetative and reproductive sides of the organism, and not monopolised and stereotyped in the production of structures at best more whimsical than useful in the great struggle for existence.

In *Ithyphallus impudicus* the sporophore originates from a white, cord-like, branched mycelium as a minute, homogeneous weft of hyphae. When about the size of a pea, a vertical section of the sporophore shows a central, boss-like, differentiated mass, comparable to the rudimentary columella or thickened base of the peridium in *Scleroderma* or *Lycoperdon*, and from this stage continues to increase in size, retaining a more or less spherical form, until it measures from 5–6 cm. diameter, when a vertical section reveals the structure shown in Fig. 44, *b*, where *d* is the gleba, *a–c* the peridium, consisting of a thin white outer membrane *a*, an equally thin inner one *c*, between the two a thick gelatinous layer *b*. The thin inner wall, *c*, is continued as a lining to the inside of the 'pileus,' *d*, and presents a honeycombed appearance, due to raised plates of tissue on its peripheral surface being arranged in polygons. This membrane carries the gleba on its peripheral side.

The axial portion is differentiated into a hollow stipe or receptaculum, which is porous in structure, the cavities before the rupture of the peridium being compressed in a direction at right angles to the long axis of the stipe (Fig. 44, *c*). When

the spores are mature the gleba assumes a dark olive-green colour and becomes watery, owing to deliquescence of the elements of the hymenium. At this stage the peridium is ruptured in an irregular manner at the apex, owing to the sudden expansion of the hitherto compressed cavities in the walls of the receptaculum, which consequently increases considerably in length, and the 'pileus' being attached to its perforated apex is elevated several inches above the ruptured volva or peridium, which remains sheathing the base of the stipe like the volva in the higher forms of *Agaricus*, with which it is at the same time homologous and analogous. After the liberation of the hymenium from the peridium it soon passes into a semi-liquid, strong-scented, dripping mass, in which the spores are imbedded, and is greedily devoured by bluebottle flies or washed off by rain, the uncoloured pileus remaining as a sheath at the apex of the receptaculum (Fig. 44). The genus *Mutinus* differs from *Ithyphallus* in not having a free pileus, the spores being borne on the modified apical portion of the receptaculum, or, as supposed by Berkeley, the pileus is adnate throughout to the receptaculum. In *M. caninus* the sporiferous portion of the receptacle is bright red, and there is little or no scent; whereas in *M. bambusinus* colour and scent are both present.

The early stage of *Clathrus*, before the peridium is ruptured, closely resembles that of *Ithyphallus*, being a white, subglobose body with a semitransparent look, and feeling rather gelatinous and elastic when pressed between the fingers. The chalk-white strand of mycelium from which it originates reaches to 1 mm. diameter, and if carefully followed will usually be found much branched and giving origin to several sporophores, varying in size from 1 mm. to 5 or 6 cm. in diameter. The peridium consists of an external and internal thin membrane enclosing a thick gelatinous layer; the latter is not homogeneous as in *Ithyphallus*, but traversed by anastomosing plates of tissue uniting the inner and outer membranes. The central portion of the sporophore forms a columella, from the surface of which are given off the tramal plates of the gleba, which occupies the

space between the columella and the inner membrane of the peridium. The receptaculum in the expanded state forms a hollow sphere from 6–8 cm. in diameter, the wall consisting of an irregular lattice-work, and has been shown by Tulasne[1] to originate from the inner membrane of the peridium at those points where the septa connecting the outer and inner walls coalesce with the latter. The structure of the receptaculum agrees with that of *Ithyphallus*, and when expanded is of a bright red colour. The gleba and central columella are carried up inside the receptaculum, and soon pass into a dripping olive-green mass, possessed of an almost insupportable odour, which is however highly appreciated by flies.

In *Aseroe*, which is sometimes met with in greenhouses, having been introduced with exotics, the receptaculum, when expanded, resembles a stipitate sea-anemone; the thick basal portion divides at the apex into a varying number of dichotomous rays, which are at first inflexed and surround the gleba, the rays, which are of a bright red colour, afterwards spread out carrying the disintegrated remains of the hymenium. The two marked features of the order are, the presence of a receptaculum and the deliquescence of the gleba into a semi-liquid mass containing the spores. There is no trace of a capillitium.

Affinities.

The discovery of basidia in the Hymenogastreae is due to Klotzsch[2], who figured and described these structures in *Hymenangium virens*, Klotzsch, but the author did not realise the importance of his discovery, and rather considered the species as not belonging to the Gastromycetes on account of the presence of basidia, and it remained for Berkeley, in an article on the fructification of *Lycoperdon*, *Phallus*, and other genera[3], to show that in all essential points, and more especially

[1] Expl. sc. d'Algérie.

[2] Dietrich's Flora Regni Borussici, vol. vi. t. 382 (1838).

[3] On the fructification of *Lycoperdon*, *Phallus*, and their allied genera, see Ann. Nat. Hist. vol. IV. p. 155 (1840).

in the presence of basidia, the hymenium in the Gastromycetes agreed with that of the Hymenomycetes. In the same place attention is called to the resemblance between the cavities of the gleba lined with basidia, and the pores in *Boletus*. In another place[1] Berkeley clearly expresses his opinion that the genera *Secotium* and *Polyplocium* may be considered as connecting links between the Hymenomycetes and Gastromycetes. Following Berkeley, De Bary considers the Gastromycetes to be derived from the Hymenomycetes, and from the following paragraph we learn that the presence of basidia in the two groups is considered as affording the proof of affinity: 'We must assume a direct affinity or phylogenetic connection throughout the whole assemblage of the Basidiomycetes. The course of development is the same in its main features wherever it has been ascertained. The organs which have been designated by the same name in the foregoing account, especially the basidia and basidiospores, must from the data before us be regarded as strictly homologous[2].' The same author further considers the Polyporeae as the order from which the Gastromycetes originated. '*Gautieria*, and we may say also some forms of *Secotium*, are evidently connecting links between the groups of the Hymenogastreae and the Polyporeae. *Gautieria*, which has all the characters of the Hymenogastreae, but has its chambers open and covered with no peridium, may be compared to a curled *Merulius*; the question naturally arises, whether the interior chambers have been formed by differentiation or in some way directly corresponding to this comparison[3].' The genera *Gautieria* and *Secotium* are presumably considered by De Bary as connecting links on account of the general resemblance of the gleba to the hymenium of some species of *Boletus* and *Merulius*, but the components of the hymenium are markedly different in the two cases. In *Boletus* and *Merulius*, as in all the Polyporeae, the basidia are constantly tetrasporous, whereas in *Secotium*

[1] On two Hymenomycetous Fungi belonging to the Lycoperdaceous group, see Hook. Journ. Bot. vol. ii. p. 200 (3 Plates).

[2] De Bary, l. c. p. 337.

[3] l. c. p. 337.

and *Gautieria* the basidia are irregular in form and produce a variable number of spores, as is usual in most of the Hymenogastreae. Berkeley considers *Gautieria* as belonging to the Clavarieae, and nearest to *Sparassis*, which is often so much curled that the normal sporiferous external surface becomes in some parts converted into sinuous closed cavities. Evidence of affinity derived from the general structure and habit of the sporophore is stated by De Bary as follows: 'If we could attribute a decisive value to the habit of the plants we should dwell upon the great resemblance between the stalked Hymenogastreae, like *Secotium erythrocephalum* and a veiled *Boletus*, or still more perhaps that of *Polyplocium* to the same species, though *Polyplocium* is too little known in its earlier states. But among the Polyporeae there is a remarkable form, *Polyporus volvatus*, Pk., the *Polyporus obvallatus* of Berk. and Cooke, which considered by itself must be placed with, or close to, the Hymenogastreae. Its sporophore which lives in the bark of trees, is a hollow spherical body flattened at the poles, and about the size of a hazel-nut, with a thick closed wall of leathery texture; its interior surface is covered with the hymenium of a *Polyporus* on the part next the substratum and is sterile on the opposite side[1].' With regard to the above description, De Bary must have been misled by the examination of a very young and imperfect specimen, and has evidently mistaken the apex for the base. The species has been very fully described and figured by Peck[2], who states that it is gregarious in habit, growing on the dead trunks of *Abies nigra* and one or two other coniferous trees, not in the bark but laterally from it, and is often furnished with a short stem. The stratum of pores, 4–5 mm. long, and very uniform, originates from the underside of the lateral pileus, the most remarkable peculiarity being the prolongation of the margin of the pileus which extends beyond the pores and becomes curved under, at first concealing the hymenium. 'In two of

[1] l. c. 337.

[2] *Polyporus volvatus*, Peck, and its varieties, Bull. Torr. Bot. Club, vol. vi. n. 10, p. 102.

the varieties the veil opens below by a well-defined circular or subelliptical aperture. In the variety *Torreyi*, no aperture has yet been seen, but one probably exists in fully and properly developed specimens[1].' In *Polyporus betulinus*, as pointed out by Peck, there is a barren margin extending beyond the stratum of pores and incurved, but to a much less extent than in *P. volvatus*, and the same character is presented by other species. From the above description it will be seen that De Bary's views as to the affinities of *Polyporus volvatus* are untenable. The last paragraph dealing with De Bary's attempts to prove the evolution of the Gastromycetes from the Polyporeae is as follows: 'It would be possible to assume another point of connection between the Hymenomycetes and the Gastromycetes, if we regard the mode of development of the compound sporophore from one side only. Then *Amanita* among the Hymenomycetes would approach nearest to the Gastromycetes, because the first development of the parts in one and the other is the result of differentiation in the interior of the primordial coil of hyphae. Brefeld, in connection with some former suggestions of my own of this kind, has recently given decisive weight to the above consideration. But then *Amanita* is closely connected in all other respects with the series of the Agaricineae; the agreement between their propagative and especially their hymenial apparatus and that of the Gastromycetes is the very smallest possible. We might disregard this fact, and venture a jump across the intervening space, if no better means of connecting these groups could be found. But since we have such a mode before us, and at the same time there is no ground for assuming the existence of two points of union, the jump need not be made. The facts lead to the other conclusion, that the development of the compound sporophores by internal differentiation, called above the angiocarpous, makes its appearance at two widely separated points within the group of the Basidiomycetes, namely, in the series of the Agari-

[1] Peck, l. c. p. 102.

cineae and in that of the Polyporeae. From the Polyporeae it leads further on to the formation of the Gastromycetes[1].' It is important to observe that De Bary admits the independent origin of the hymenial portion from internal differentiation at two widely separated points in the Basidiomycetes, and further, that the dissimilarity between their hymenial apparatus prevents the Gastromycetes from being considered as originating from the higher Agaricineae. The great objection to De Bary's view of the origin of the Gastromycetes, excepting the cases mentioned above, which certainly do not appear to be convincing, consists in the marked disagreement of every feature considered by De Bary as being of greatest importance. As already stated, the leading characters of the Hymenogastreae are: subterranean habit; homogeneous peridium, remaining intact until the spores are mature; irregularly formed basidia bearing a variable number of spores, which are very large, coarsely warted or spinulose, and highly coloured. In the Polyporeae, all the species grow exposed to light, on the ground, or more frequently on decaying wood, and in the greater number the hymenium is from the first exposed, being protected during the early period by a veil in only a few of the higher forms of *Polyporus* and *Boletus*; the basidia are very uniform in shape and constantly tetrasporous, the spores being small in size, always smooth, and generally colourless or at most very faintly tinged, except in *Merulius lacrymans*, where they are orange-brown, a colour not met with in the Hymenogastreae. The broad features presented by the two groups respectively, are to my mind diametrically opposed to any idea implying the outgrowth of the one from the other.

It has been already stated that the Hymenogastreae constitute the starting-point of the Gastromycetes, as was pointed out long ago by De Bary, as follows: 'That all the groups of the Gastromycetes converge towards the Hymenogastreae

[1] l. c. p. 338.

directly or indirectly through the Lycoperdaceae, and that they may therefore be deduced phylogenetically from the Hymenogastreae, is a necessary conclusion from the account which has been given of them[1].' If the Hymenogastreae are accepted as the primitive stock of the Gastromycetes, it might not be considered unreasonable to seek for their ancestors amongst groups of fungi possessing the same marked peculiarity of being subterranean in habit, and the order that naturally suggests itself in this particular is the Tuberaceae, the morphology of which up to a certain point is also identical with that of the Hymenogastreae. There is the same thick, comparatively undifferentiated, indehiscent peridium, completely enclosing the gleba broken up into numerous sinuous cavities by the tramal plates, which are continuous with the inner surface of the peridium, the same very large, warted or spinulose, coloured spores,—but the spores are produced in asci, unmistakably so in typical species. It has been shown by Tulasne[2], that the hymenial elements, more especially the asci, are quite as inconstant in shape, size, and number of contained spores, in the Tuberaceae, as the basidia are in the Hymenogastreae; it is not unusual to meet with asci containing from one to four spores respectively in the same species of *Tuber*, and the same is true of other genera. Tulasne has removed the genus *Elaphomyces* from the Tuberaceae, and established for its reception a new order, Elaphomycei, which he considers as intermediate between the Tuberaceae and the Gastromycetes, inasmuch as the genus embodies certain important features characteristic of each; agreeing with the former in having the spores produced in asci, and absence of a thickened sterile basal portion of the peridium; and with the latter in the spores when mature forming a powdery mass, and mixed with a capillitium. 'Elaphomycetes Tuberaceis genuinis quoad fructificationem analogi, structura morphisque floccoso-pulveracea sicca ab eis toto coelo differunt, et ad Lycoperdeos basidiosporas accedunt, quapropter fungos utri-

[1] l. c. p. 337.

[2] Fung. Hypog. p. 101.

usque familiae medii connectere videtur[1].' In the generic diagnosis of the genus *Elaphomyces* Tulasne describes the asci as follows: '*Sporangia*, floccorum fertilium extremae cellulae maxime turgidae et in sacculos mutatae, globoso obovatae, brevissime pedicellata, hyalina, 1–8 spora[2].' In Corda's genus *Phlyctospora*, classed with the Tuberaceae, the asci are normally monosporous, but the ascus breaks away from its support and remains as a permanent hyaline sac surrounding the spore. Corda's explanation is as follows: 'Sporae aggregatae, compositae, decolorantes, substantia immersae; *episporio* [ascus] celluloso hyalino, *nucleo* [spore] globoso colorato, firmo. Asci v. basidia nulla[3].' Tulasne states that in the species of *Hymenogaster*, the spores, while yet attached to the basidia, are surrounded by a hyaline membrane many times larger than the diameter of the spore, and an examination of the figures of *Hysterangium clathroides* (t. xi, f. vii), *Rhizopogon luteolus* (t. xi, f. v[8]), *Hymenogaster decorus* (t. x, f. 9[2]), and others, suggests the idea of the asci being bifurcate at the apex. I have only been able to examine *Hymenogaster tener* and *H. citrinus* in connection with this idea, and am satisfied that the two spores borne by the basidia depend on the bifurcation of the basidium at the apex, and first appear as two sessile terminal papillae (Fig. 1, f); as the papillae increase in size, each becomes constricted at the base (Fig. 1, *a*), and forms an apparent sterigma; eventually the protoplasm in each papilla secrets a cell-wall, which becomes rough and coloured, and is now a spore, still surrounded by the original wall of the ascus. Before the cell-wall is secreted by the spore, a transverse septum forms across the sterigma, and the protoplasm in the spore-sac rounds itself off. Berkeley noticed long ago that the spores in many of the Hymenogastreae were at first sessile, the sterigma being an after-development; but this is not true of all species, compare Fig. 2, *a*, and in the higher orders the sterigmata are formed before the spores, but the latter are

[1] Tul., Fung Hypog. 101.
[2] Tul. l. c. p. 101.
[3] Corda, Sturm, Deutschl. Fl., III^te Abtheil., 19–20 Heft (1841), p. 51.

produced as in *Hymenogaster*; hence, if the above account is correct, the Gastromycetes have been derived from the Ascomycetes through the Tuberaceae, by the gradual conversion of asci into basidia. The evolution of the Hymenomycetes from the Ascomycetes, through the Uredineae, first pointed out by De Bary, is now generally accepted; and it may be urged against the above idea, that it is improbable there should be two independent starting-points for the Basidiomycetes; yet it may perhaps not be more improbable than that there should be two independent formations of the hymenium, etc., by differentiation in the interior of the primordial coil of hyphae at widely separated points in the Hymenomycetes, as stated by De Bary.

Distribution.

There are about six hundred known species belonging to the Gastromycetes, of which two hundred are European. In Great Britain we have twenty-one genera, including seventy-four species, which is rather poor compared to the numbers found in France and Germany, the former having one hundred, the latter one hundred and five species.

The Phalloideae, numbering about seventy-four species, are mostly tropical or subtropical, but extending in numbers further south than north. There are four known European species, three of which are British. *Clathrus cancellatus* reaching its northern limit on the south coast, *Ithyphallus impudicus* and *Mutinus caninus* reach the north of Britain, the former extending to North America and Japan. The extra-British species, *Colus hirundinosus*, is in Europe confined to the south of France and Spain, and has been collected in Algeria, West Australia, and Cayenne.

The Hymenogastreae, as would be expected from their subterranean habit, have only been collected where specially looked for, and are up to the present most abundant in western and central Europe; our own twenty-three species being largely due to the researches of Berkeley and Broome.

The Nidularieae, although a small group, have a world-wide distribution.

The Sclerodermeae and Lycoperdeae are characteristic of temperate regions, although a few genera, as *Calostoma*, are most abundant in warm regions. *Lycoperdon*, numbering one hundred and thirty species, is widely distributed in both north and south temperate zones, eighty-seven species are confined to the northern hemisphere, twenty-eight to the southern, and fifteen are common to both: the tropical species usually occur at considerable elevations; *Lycoperdon gemmatum*, a common British species, was collected by Dr. (now Sir Joseph) Hooker between seven and eight thousand feet in the Himalayas, and *L. Emodense*, an extra-European species, in the same locality at an elevation of between nine and ten thousand feet. *Bovista pusilla*, a British species usually less than an inch in diameter, is represented in the Royal Herbarium, Kew, from Europe, North America, South America, Tropical and South Africa, Lower Pegu, East Nepal, Java, Ceylon, China, Bonin Islands, Australia, and New Zealand.

To the British student of Mycology, the genera may appear to be well defined, but it is important to remember that this is due to the fragmentary nature of the flora, and it is only when the whole group is examined that the limitation of genera becomes a matter of difficulty. The following list of all known genera belonging to the Gastromycetes will give some idea as to the relative position of British genera, which are printed in capitals. The number following each genus indicates the number of species, and the bracketted number gives the number of British species in each genus:—

GASTROMYCETES.

HYMENOGASTREAE.

HYSTERANGIUM, 9. (2).
OCTAVIANIA, 8. (3).
RHIZOPOGON, 11. (2).
MELANOGASTER, 9. (2).
HYMENOGASTER, 24. (12).
HYDNANGIUM, 7. (2).
Gautieria, 4.
Macowanites, 1.

SCLERODERMEAE.

Polygaster, 1.
SCLERODERMA, 30. (4).
POLYSACCUM, 15. (1).
Arachnion, 4.
Scoleciocarpus, 1.
Paurocotylis, 4.
Ciliciocarpus, 1.
Lycogalopsis, 1.
Glischroderma, 1.

NIDULARIEAE.

NIDULARIA, 14. (4).
CYATHUS, 34. (2).
CRUCIBULUM, 2. (1)
THELEBOLUS, 4. (1).
Dacryobolus, 2.
SPHAEROBOLUS, 5. (1).

PODAXINEAE.

Gyrophragmium, 1.
Secotium, 15.
Polyplocium, 2.
Mesophellia, 3.
Cauloglossum, 3.
Podaxon, 6.
Sphaericeps, 1.

LYCOPERDEAE.

TULOSTOMA, 19. (1).
Queletia, 1.
BATTARREA, 5. (1).
Calostoma, 8.
GEASTER, 54. (13).
Cycloderma, 3.
Diplocystis, 4.
Diploderma, 3.
Trichaster, 1.
Broomeia, 2.
Coilomyces, 1.
Lanopila, 4.
Eriosphaera, 1.
BOVISTA, 38. (7).
Calvatia, 2.
LYCOPERDON, 130. (12).
Hippoperdon, 5.
Castoreum, 1.
Xylopodium, 3.
Areolaria, 3.
Phellorinia, 3.
Favillea, 1.

PHALLOIDEAE.

Dictyophora, 15.
ITHYPHALLUS, 12. (1).
MUTINUS, 11. (1).
Kalchbrennera, 1.
Simblum, 7.
CLATHRUS, 11. (1).
Colus, 2.
Lysurus, 3.
Anthurus, 5.
Calathiscus, 2.
Aseroe, 5.

HYMENOGASTREAE.

Peridium indehiscent; gleba broken up by septa into numerous irregular cavities; capillitium absent; subterranean.

Hymenogastreae, Tul., Fl. d'Algérie, i, p. 394.

Hymenogastrei, Tul., Fung. Hypog. p. 61.

Hypogaei, Berk., Outl. p. 292.

OCTAVIANIA, Vitt.

Peridium continuous or cracked, cottony, running down into a well-developed sterile base; trama byssoid, easily divisible; cells at first empty, peripheral ones small, spherical, central ones much larger and irregular, spores rough.

Octaviania, Vitt., Mon. Tub. p. 15 (in part); Corda, Ic. Fung. v, p. 26; Fr. Summ. Veg. Scand. p. 436; Sacc. Syll. vii, p. 158.

Distinguished from *Hydnangium* by the presence of a sterile basal stratum, and from *Melanogaster* in the cavities of the gleba being at first empty, and the septa byssoid.

Octaviania asterosperma, Vitt. (Fig. 2). Globose or irregular, dirty-white, then aeruginous-blue or black in parts, sterile base thickish, cells irregular, central ones largest; spores globose, coarsely echinulate, brown, 14–15 μ diam.

Octaviania asterosperma, Vitt., Mon. Tub. 17, t. iii, f. 7; Tul., Ann. Sc. Nat. sér. 2, xix, p. 276, Pl. xvii, f. 21; Tul., Fung. Hypog. 77, t. xi, f. 1; Corda, Ic. Fung. vi, t. vii, f. 64; Berk., Outl. 292; Cke., Hdbk. n. 1045; Wint., Kr. Fl. 878; Sacc. Syll. vii, p. 159.

Lyndhurst! Bristol! Chudleigh! Bowood!—Europe; N. Africa.

From ¾–1½ in. across, globose or irregular, mycelium abundant, adhering to twigs or leaves underground. Peridium continuous or cracked into areolae, minutely downy, whitish, changing to greenish-blue or black when touched and exposed to the air.

Octaviania Stephensii (Berk.), Tul. (Fig. 3). Irregular, oblong, externally rufous, base rugoso-plicate, cribrous, furnished

with a branched fibrous root; inside white, yielding when cut a white milky fluid, substance becoming red when exposed to the air; cells minute, spores globose echinulate, pale brown, 11–14 μ diam.

Octaviania Stephensii, Tul., Fung. Hypog., p. 78, Pl. xxi, f. vi. (the spores are correctly described by Tulasne as globose, but in the figure are represented as broadly elliptical, and the spines are too large). Berk., Outl. 292; Cke., Hdbk. n. 1046; Sacc. Syll. vii, p. 159.

Hydnangium Stephensii, Berk., Ann. Nat. Hist. xiii, p. 352. In Ann. Nat. Hist. xviii, p. 76, Berkeley and Broome, speaking of the genus *Octaviana*, say, 'It is probable that *Hydnangium Stephensii* really belongs to this genus, and that *H. carotaecolor* is a true *Hydnangium*. The structure of the trama is very different, in the former resembling that of an Agaric, in the latter that of a *Russula*.'

(Type in Herb. Berk. Kew, n. 4435.)

Clifton!—Exs.—Rab., Fung. Eur. 1319.

About ¾ of an inch in diameter, oblong, attached by a branched fibrous root, smooth, not cracked, dark rufous, curiously plicate at the base and cribrous; within white, yielding when cut a white milky fluid; substance when cut and exposed to the air soon acquiring a red tinge, which is not however permanent, and in young specimens vanishes almost entirely in drying, in which state the hymenium is cream-coloured; cells minute; spores at first irregularly globose, with a broad rugulose border, somewhat after the fashion of the young spores of *Scleroderma*, at length echinulate.

This is a very curious species, remarkable for its milky juice, smooth dark peridium, and plicate base. I have not seen it with the sporophores perfect. It cannot be confounded with any other hypogaeous fungus. The smell in my specimens was slight, resembling that of *Agaricus theiogalus*. (M. J. B., l. c.)

Octaviania compacta, Tul. (Fig. 12). Small; gregarious; peridium globose or irregular, white, minutely cottony;

cells globose or irregularly oblong, minute, soon filled with spores, septa indistinct; spores minute, globose, very minutely verruculose, pale yellow, becoming brighter, 5–6 μ diam.

Octaviania compacta, Tul., Giorn. Bot. Ital. ii, p. 56; Tul., Hypog. p. 79, t. xi, f. 3; Sacc., Syll. vii, p. 160.

Exs.—Rab., Fung. Eur. 2502.

Underground or half-buried. Shoreham, Kent! Hillydeal wood, Otford, Kent!—France.

From ¼–½ inch across, furnished with a dense rooting mass of pure white mycelium. An anomalous species, referred by Tulasne to *Octaviania* with some hesitation, and presenting no close affinities with any known genus.

MELANOGASTER, Corda.

Peridium without any proper or distinct base, branched fibres springing from every part of its surface. Cells of gleba more or less rounded, large in the centre, and becoming smaller towards the periphery, septa thick, continuous with the peridium. Spores 3–4, subsessile on the basidia, smooth, generally coloured.

Melanogaster, Corda, ap. Sturm, Deutsch. Fl., iii. 11, p. 1; Tul., Fung. Hypog. 92, t. ii, f. 4–6, and t. xi, f. 5–7; Sacc., Syll. vii, p. 164.

The absence of a distinct rooting base, branched fibres traversing the whole surface of the peridium, and smooth spores, are the characteristic features of the present genus.

Melanogaster variegatus, Tul. (Fig. 10). Irregularly globose, at first ochraceous or clear yellow, then reddish ferruginous, with adpressed tomentum, tramal plates whitish, then bright orange, pulp black; spores brown, elliptic-oblong, 10 × 5 μ.

Melanogaster variegatus, Tul., Ann. Sci. Nat. sér. 11, xix, t. xvii, f. 22; Tul., Fl. Alg. i, 397; Tul., Fung. Hypog. p. 92, t. xi, f. 4, and t. xii, f. vi; Sacc., Syll. vii, p. 165.

Octaviania variegata, Vitt., Mon. Tub. p. 16, t. iii, f. 4.

Tuber moschatum, Bull., Champ. I. 79, t. 479.

Exs.—Fuckel, Fung. Rhen. 1249.
Bristol! Rudloe, Wilts!—France.

Var. **Broomeianus**, Berk.

Gregarious, globose or irregular, at first ochraceous, then reddish ferruginous, minutely downy; walls of the cells dirty-white or yellowish; pulp black; spores elliptic-oblong, smooth, clear brown, 9–10 × 4–5 μ.

Melanogaster Broomeianus, Berk., Ann. Nat. Hist. xiii, 352; Tul., Ann. Sci. Nat. sér. 2, t. xix, 377, t. xvii, f. 23; Sacc., Syll. vii, p. 165.

Melanogaster variegatus, var. *Broomeianus*, Berk., Outl. 293; Tul., Fung. Hypog. 93, t. xi, f. iv–vi^{b}; Cke., Hdbk. n. 1047.

Tuber moschatum, Sow., Eng. Fung. t. 426.

Exs.—Berk., Brit. Fung. 285.

Under beech trees, Lombardy poplars, etc. Rudloe! Bury St. Edmund's! Clifton!

Differs from the type which has not been collected in Britain, in never having the walls of the cells bright yellow or orange.

Sold in the market at Bath under the name of Red Truffle, and eaten there in preference to the Common Truffle. In tufts of five or six together, and several of such tufts under each tree, half of them being in general exposed, and half beneath the soil; when fresh it is minutely tomentose, of a reddish-ochre, which becomes less bright when handled or badly dried; the veins bright yellow in the typical form, pale in the variety, sometimes becoming red when dry, sometimes unchangeable; at first white within, then very pale yellow, at length fuliginous. (M. J. B., l. c.)

Melanogaster ambiguus, Tul. (Fig. 5). Globose or ellipsoid, very foetid, nearly even, pale olive, becoming brownish when exposed to the air, septa white, spores obovate or elliptical, apex variable, acute, or obtuse and papillate, smooth, brown, 13–15 × 7–8 μ.

Melanogaster ambiguus, Tul., Ann. Sc. Nat. sér. 2, t.

xix, p. 337, t. xvii, f. 24; Tul., Fung. Hyp. 94, t. ii, f. 5, and t. xi, f. 5; Berk., Ann. Nat. Hist. xiii, 354; Berk., Outl. 293; Corda, Ic. Fung. vi, t. ix, f. 88; Cke., Hdbk. n. 1048; Quel., Enchirid. 245; Wint., Kr. Fl. 883; Sacc., Syll. vii, p. 165.

Melanogaster Klotzschii, Cda., c. Fung. v, 23.

Hyperrhiza liquaminosa, Klotzsch, in Dietr. Fl. des Koenigr. Preuss. t. 468.

Argylium liquaminosum, Wallr., Fl. Cr. Germ. ii, 874, *aa.*

Octaviania ambiguua, Vitt., Mon. Tub. p. 18, t. iv, f. 7.

Hyperrhiza tuberosa, Fr., Ind. S. M. 102.

Under fir-trees, etc. About 1 in. across. Apethorpe, Norths.! Sibbertoft, Norths.! Bowood, Spye Park, Wilts! Clifton! Jedburgh!—Europe, U. States.

Tulasne says that the septa are white and unchangeable; Berkeley, that they become reddish when exposed to the air. Known at once (from *M. variegatus*, var. *Broomeianus*) by its much larger ovate spores, with a papilla at the apex, and its abominable smell, which resembles that of assafoetida. A single specimen in a room is so strong as to make it scarcely habitable. The walls of the cells when cut are whitish, but soon become red; this is not, however, constantly the case.

Var. **intermedius**, Tul.

Spores obovate, obtuse, and even, very rarely slightly papillate.

Melanogaster variegatus, var. *intermedius*, Berk., Ann. Nat. Hist. xiii, 354.

Melanogaster ambiguus, β *intermedius*, Tul., Fung. Hypog. 95; Sacc., Syll. vii, p. 166 (Type in Herb. Berk. n. 4424).

This form, or more probably species, of which I have seen only an imperfect specimen, was found at Spye Park, in August, by Mr. Broome. It is as large as *M. Broomeianus* (= *M variegatus*, var. *Broomeianus*), of which it has the bright rusty colour; but the spores are much larger, equalling in size those of *M. ambiguus*, though of a very different form. There is

scarcely ever the slightest indication of a papilla, and they are obovate with a single globose nucleus. The smell resembles that of *M. ambiguus*. The walls of the cells are yellowish, and are red in the dry specimens. (M. J. B., l. c.)

HYDNANGIUM, Wallr.

Peridium fleshy or membranaceous, smooth or silky, sterile base not developed; trama vesicular, cells minute, unequal, at first empty, then filled with spores; spores globose or subglobose, echinulate.

Hydnangium, Wallr., ms.; Tul., Ann. Sci. Nat. sér. 2, xix, p. 376; Fr., Summa. Veg. Scand. p. 436; Sacc., Syll. vii, p. 175.

The globose or subglobose echinulate spores, which are generally small, and the absence of the sterile base separate the present genus from *Octaviania*, its nearest ally.

Hydnangium carotaecolor, B. and Br. (Fig. 6). Oblong, rootless; peridium thin, rugulose, slightly tomentose, brick red, orange within; spores subelliptic, pale, coarsely echinulate, 15–18 × 11–13 μ.

Hydnangium carotaecolor, B. and Br., Ann. Nat. Hist. xiii, 351; Berk., Outl. 293, pl. xx, f. 1; Tul., Fung. Hypog. 75, t. xxi, f. 4; Cke., Hdbk. n. 1049: Quel., Enchirid. 247; Wint., Kr. Fl. 877; Sacc., Syll. vii, p. 176.

Under trees; sometimes half exposed. Bristol! Ballard's Down, Swanage!—Europe.

Oblong, ¾ in. in diameter, externally slightly tomentose, pale orange red, fleshy, but by no means deliquescent, rootless; peridium thin, at length rugulose, within minutely cellular; substance of a beautiful orange red; cells hollow, clothed with obtuse bisporous sporophores and slender cystidia; the cells are also traversed from wall to wall by slender, occasionally branched threads; spores subelliptic, strongly echinulate, supported on short but distinct sterigmata. The colour is very vivid, exactly like that of a fine carrot. When dry it communicates a lemon-coloured stain to the paper in

which it is preserved. (M. J. B.) There are often four spores on a basidium!

Hydnangium carneum, Wallr. (Fig. 14). Subglobose or irregular; flesh-coloured; inside pale flesh-coloured, unchangeable; spores globose, with long, slender, acute spinules, pale pinkish-brown, about 12 μ diam.

Hydnangium carneum, Wallr., ms.; Tul., Fung. Hypog. 75, t. xxi, f. 3; Karst., Fung. Fenn. 355; Wint., Kr. Fl. 877; Quel., Enchirid. 247; Sacc., Syll. vii, p. 175.

Exs.—Rab., Eur. n. 675.

Underground or partly exposed. In tub containing a species of *Eucalyptus*. Royal Botanic Garden, Edinburgh! Germany; Brisbane.

About ½ in. across, pinkish or flesh-coloured, at first covered with a white, fugacious down.

HYSTERANGIUM, Vitt.

Peridium truly indehiscent, distinct, separable; gleba cartilagineo-glutinous, cavities at first empty; spores minute, epispore smooth.

Hysterangium, Vitt., Mon. Tub. p. 13; Fries, Summa Veg. Sc. p. 437; Tul., Fung. Hypog. p. 80; Sacc., Syll. vii, p. 155.

Characterised by the small, elliptical, smooth spores, and the cartilaginous mucous consistence of the gleba, which resembles that of *Phallus* and *Clathrus* in the young state, as first pointed out by Vittadini. There is frequently a copious development of mycelium.

Hysterangium nephriticum, Berk. (Fig. 4). Globoso-depressed, springing from a much branched white mycelium; peridium rather thick, elastic, tomentose; substance pale blue or grey, here and there greenish; cells irregular, minute, hollow, radiating from the base; spores elliptical, smooth, very pale, about 18–20 × 5–6 μ.

Hysterangium nephriticum, Berk., Ann. Nat. Hist. xiii, p. 350; Tul., Hypog. p. 82; Berk., Outl. p. 294; Cke., Hdbk.

n. 1050; Sacc., Syll. vii, p. 156 (Type in Herb. Berk. Kew, n. 4447).

Clifton! King's Cliffe!

Above ½–1 inch across, gregarious, sometimes confluent, snow-white, downy, seated on a white, flat, branched mycelium which penetrates deeply into the clayey soil, and is attached at various points to the peridium; peridium firm, elastic, easily separating from the fructifying mass, but in the process of drying in young plants adhering closely to it, in older plants often separating entirely; when rubbed or cut contracting sometimes a pale rufous tinge; substance firm, cartilagineo-glutinous, proceeding from the base and radiating into the mass, the arrangement of which has a strong resemblance to that of a kidney, of a pale blue or grey, which in parts exhibits a green tinge from the subjacent spores; in very young specimens, before the spores are formed, there is not the slightest blue tinge, but a very pale pink; cells irregular, minute, sometimes straight and radiating, clothed with very pale argillaceous oblong spores, and emitting from their walls irregular threads which either terminate abruptly or cross over to the opposite wall. As the plant dries, the blue, and consequently the green, tint, vanishes almost entirely, and the mass is of a very pale clay-colour from the spores. The central mass contracts extremely, and the outer surface becomes more or less irregular. Smell scarcely any at first, then like that of some *Hypericum*, at length precisely like that of a decaying puff-ball. If the fungus is cut exactly through the centre, the arrangement of its tissue is seen distinctly to proceed from the base. This species is doubtless extremely near to *H. pompholyx*, of which I have specimens from Messrs. Tulasne, but it is larger; the peridium is firm, and in old specimens does not contract together with the central mass; the spores not rose-coloured, and perhaps rather larger. (M. J. B., l. c.)

Hysterangium Thwaitesii, B. and Br. (Fig. 80). Subglobose, white, becoming rufous when touched, peridium membranaceous; spores oblong, apiculate, pale olive, 25–30 × 7–9 μ.

Hysterangium Thwaitesii, B. and Br., Ann. Nat. Hist. sér. 2, ii, p. 267 (1848); Tul., Fung. Hypog. p. 82; Cooke, Hdbk. n. 1051; Sacc., Syll. vii, p. 156.

Splanchnomyces membranaceus, Corda, Ic. Fung. v, vi ?

Leigh Wood, Bristol! (Type in Herb. Kew.)

Mycelium white, fibrillose, not much to form membranous expansions, spreading for some distance. Sporangium globose or slightly irregular, white, slightly silky, when rubbed or exposed to the air assuming a rufous tinge. Peridium membranous, not so thick as in *H. nephriticum*, though as in that species it sometimes separates when dry; rufous when divided. Cells brownish olive. Spores oblong, apiculate, differently shaped from those of the other species, and comparable only with those of *H. membranaceum*, Corda (Berk.).

RHIZOPOGON, Tul.

Peridium thick, subcoriaceous, or sub-membranaceous, continuous or cracked and subevanescent, with vein-like branched fibres traversing its surface; substance of gleba firm, cavities distinct, at first empty; spores smooth.

Rhizopogon, Tul., Giorn. Bot. Ital. ii. p. 56; Sacc., Syll. vii, p. 161.

The cord-like branched mycelium adnate to the surface of the peridium is characteristic of the above genus, which resembles *Hysterangium* in the smooth eliptical spores.

Rhizopogon rubescens, Tul. (Fig. 7). Ovate or globose, with a long slender rooting mycelium, at first white and silky, becoming reddish when exposed to the air, when mature yellow or olive; flesh yellow, then pale olive; cells numerous, small, irregular; spores elliptic-oblong, almost colourless, smooth, 11 × 4–5 μ.

Rhizopogon rubescens, Tul., Giorn. Bot. Ital. ii, 58 (excl. syn. Friesii); B. and Br., Ann. Nat. Hist. xviii, 76; Berk., Outl. 294; Cke., Hdbk. n. 1052; Tul., Fung. Hypog. 89, t. xi, f. iv, t. ii, f. 1; Sacc. Syll., vii, p. 161.

Rhizopogon albus, Fl., Cr. Germ. ii, p. 886, n. 4148 (excl. syn.); Wint., Kr. Fl. 881.

Rhizopogon luteolus, Krombh., t. 60, f. 13–15.

Rhizopogon aestivus, Fr., S. M. ii, 294.

Hysterangium rubescens, Tul., Ann. Sci. Nat. sér. 2, xix, 375.

Melanogaster Berkeleyanus, Broome, Ann. and Mag. Nat. Hist. xv, 41.

Melanogaster Broomeianus, Cda., Ic. Fung. vi, t. xi, f. 90.

Exs.—Desm., Cr. Fr. sér. 1, 767 and sér. 2, 263; Rav., Fung. Car. 75; Ellis, N. Amer. 943; Fuckel, Fung. Rhen. 1251; Roum., Fung. Gall. 2811; Rab., Fung. Eur. 1279.

Lyndhurst! Wraxall, Somerset! Chudleigh! Ayr! Forres, N.B.!—Europe; U. States.

This species occurred last year abundantly at Chudleigh, and appears to be certainly the same with the species of Tulasne. *Hysteromyces graveolens*, Vitt., of which authentic specimens have been kindly communicated, is probably also the same species, as is also the case with *Rhizopogon luteolus* and *R. virens* from Italy, *Hymenangium virens*, Kl., *Rhizopogon luteolus*, Corda, and perhaps with *Rhizopogon luteolus*, Fr.

This species grows gregariously in sandy fir-woods. When young it is almost transparent, and resembles young *Phallus caninus*, being of a pure white, and furnished with white roots which proceed from a mycelium which spreads sometimes an inch or two; in this state it turns pink on being touched; in a more advanced stage it is yellow, but even then it has here and there a pink tinge. The smell is very much like that of *Melanogaster ambiguus* when old, but when young it has an acid smell like that of sour ham. It rapidly decays into a brown fetid pulpy mass. (B. and Br., l. c.).

Rhizopogon luteolus, Tul. (Fig. 9). Globose, or oblong-ovate, from whitish becoming dirty yellow, then olive-brown, clothed with numerous slender, free or adnate mycelium strands, peridium thick, subcoriaceous, cells minute, rounded, subequal, at first empty, becoming stuffed, septa whitish,

spores narrowly elliptic, smooth, for a long time colourless, then pale olive, 8 × 3 μ.

Rhizopogon luteolus, Tul., Giorn. Bot. Ital. ii, 57; Fr., Syst. Myc. ii. 294 (excl. syn. Mentzelii and Gleditzschii); Fr., Summ. Veg. Scand. 435; Wahlenb., Fl. Suec. ii, 997; Tul., Fung. Hypog. 87, t. i, f. 5, and t. xi, f. 5; Karst., Myc. Fenn. 354; Quel., Enchirid. 246; Wint., Kr. Fl. 880; Sacc., Syll. vii, p. 161.

Hysterangium Duriaeanum, Tul., in Chautelat, Cat. pl. de la Teste-de-Buch, 75 (Actes de la Soc. Linn. bordelaise, xiii, 1844).

Tuber virens, Alb. et Schw., Cons. Fung. Lusat. 77, t. viii, f. 3.

Exs. — Fuckel, Fung. Rhen. 1250; Roum., Fung. Gall. 2316: Sydow, Myc. March. 386; Klotzsch, 320; Rab., Fung. Eur. 570; Moug. and Nest., 1275; Desm., Cr. Fr. sér. 1, 1513; Westendorp Herb., Cr. Belg. 39; Rab. (Wint.), Fung. Eur. 2940.

Underground or partly exposed, solitary or gregarious, in sandy pine woods, etc. Scotland!—Europe; Florida; California; China; Australia; New Zealand.

From ⅜–1½ in. across, smell at first weak, then strong and offensive. Taste insipid.

Hymenogaster, Tul.

Globose or irregular; peridium fleshy or thin, simple, homogeneous, running down into a sterile base; cavities of gleba at first empty, radiating from the base or irregularly scattered; trama composed of elongated cells, but not of byssoid flocci, and therefore not easily separable; spores elliptical or fusiform.

Hymenogaster, Tul., Fung. Hypog. 63; Vitt., Mon. Tub. p. 20 (in part); Sacc., Syll. vii, p. 168.

Splanchnomyces, Corda, Ic. Fung. vi.

The large elliptical or fusiform, rugulose or nodulose spores, cavities of the gleba empty at first, and sterile basal stratum of the peridium, mark the genus.

Hymenogaster Klotzschii, Tul. (Fig. 24). Obovate or subglobose, fibrillose at the base, dirty white, inside pallid, becoming rufous-ochre; spores broadly elliptic, ends obtuse, minutely tuberculose, pale brown, 18–20 × 11–13 μ.

Hymenogaster Klotzschii, Tul., Fung. Hypog. 64, pl x, f. xii; Berk., Outl. 295; Cke., Hdbk. n. 1053; Wint., Kr. Fl. 874; Sacc., Syll. vii, p. 170.

Hymenangium album, Klotz., in Dietr., Fl. Regni Boruss. v, 446 (excl. syn.).

Hymenogaster albus, Berk., Ann. and Mag. Nat. Hist. xiii, 349; Fr., Summ. Veg. Scand. 436.

Rhizopogon albus, Berk., Eng. Flor. 229.

Exs.—Rab., Fung. Eur. 142; Karst., Fung. Fenn. 484.

In pot in greenhouse, Royal Botanic Garden, Edinburgh! Tunbridge Wells!—Europe.

About the size of a hazel-nut, peridium white, becoming yellowish, clothed with adpressed down, rooting fibres slender.

Hymenogaster muticus, B. and Br. (Fig. 20). Globose, quite white when young, then tinged with brown and cracked, pale yellow-brown within, spores obovate, oblong, very obtuse, pale brown, 18–21 × 10–12 μ.

Hymenogaster muticus, B. and Br., Ann. Nat. Hist., sér. 2, ii, p. 267; Berk., Outl. 295; Tul., Fung. Hypog. 65, t. x, f. 7; Cke., Hdbk. n. 1054; Sacc., Syll. vii, p. 172. (Type in Herb. Berk. Kew, no. 4459.)

Stapleton Grove near Bristol!

About an inch in diameter, almost destitute of any absorbing base, globose, scarcely at all lobed. When young at first pure white, but changing with age, especially when rubbed, to brownish, and at length much cracked. Substance pale yellowish-brown, rather firm and dry; cells loose, but smaller than in some of the allied species, clothed with reddish brown obovate oblong spores, which for the most part are quite obtuse, without the slightest trace of an apiculus, and contain two or three variously sized oil globules, smell very slight.

Distinguished from all its more immediate allies by its

peculiar spores. It resembles much in general appearance *H. olivaceus.* The spores of *H. lilacinus*, Tul., are sometimes similarly shaped, but not typically, a point which requires strict attention in this genus. (B. and Br.)

Hymenogaster luteus, Vitt. (Fig. 18). Subglobose, of medium size, peridium very thin, soft, and silky, white, then brownish, bright yellow within; spores smooth, oval or elliptic, yellowish, 24–28 × 10 μ.

Hymenogaster luteus, Vitt., Mon. Tub. 22, t. iii, f. 9; Tul., Ann Sci. Nat. sér. 2, xix, p. 374, pl. xvii, f. 11–13; Berk., Ann. Nat. Hist. xiii, p. 347, and xviii, p. 73; Berk., Outl. 295; Tul., Fung. Hypog. 65, t. i, f. 3; Cke., Hdbk. n. 1055; Wint., Kr. Fl. 875; Quel., Enchirid. 248; Sacc., Syll. vii, f. 171.

Splanchnomyces luteus, Cda., Ic. Fung. vi, t. viii, f. 76.

Exs.—Rab., Fung. Eur. 1322.

(Specimen from Vittadini in Herb. Berk.)

Not uncommon. Castle Coombe! Rudloe! Apethorpe! Rushton! Audley End, Essex! Corsham, Wilts! King's Weston, near Bristol!—France; Italy.

Distinguished by its bright, permanently yellow hymenium, and smooth, papillate, very variable, often triangular spores. The tint varies according to the quantity of spores. Some specimens have but little scent, others, especially the larger ones, are powerfully foetid. (M. J. B.)

Hymenogaster decorus, Tul. (Fig. 22). Roundish, dirty white, becoming yellowish in places, within lilac-brown, at length blackish, sterile base almost obsolete; basidia long, slender; spores broadly elliptical obtuse or obtusely apiculate, rugulose, ochraceous, then brown, 24–28 × 13–15 μ.

Hymenogaster decorus, Tul., Ann. Sci. Nat. sér. 2. xix, p. 374, pl. xvii, f. 4–8; Tul., Fung. Hypog. p. 67, tab. x, f. 9; Berk., Outl. p. 295; Cke., Hdbk. n. 1056; Wint., Kr. Fl. 876; Quel., Enchirid. 249; Sacc., Syll. vii, p. 169.

Exs.—Rab., Fung. Eur. 1321.

In woods. Bristol! Chudleigh! King's Weston! Epping Forest! France.

Size of a walnut, sometimes smaller. Remarkable for the long slender basidia which project into the cavities, often monosporous, and sometimes flexuous, sometimes bisporous with sterigmata of variable length.

Hymenogaster vulgaris, Tul. (Fig. 13). Subrotund, irregular, whitish, becoming discoloured, rather soft; gleba dirty white, then dark brown, cavities irregular, rather large; sterile base minute; spores oblong or oblong-lanceolate, acute, attenuated at the base, blackish-brown when mature, rugulose, 34–40 × 12–14 μ.

Hymenogaster vulgaris, Tul., ms.; Berk. and Br., Ann. Nat. Hist. xviii, p. 74; Tul., Fung. Hypog. 67, t. x, f. 13; Berk., Outl. 296; Cke., Hdbk. n. 1057; Sacc., Syll. vii, p. 175.

Hymenogaster griseus, Tul., Ann. Sci. Nat. sér. 2, xix, p. 374, pl. xxvii, f. 1–3 (not of Vitt.); Karst., Myc. Fenn. 355.

Splanchnomyces tener, Corda, Ic. Fung. vi, t. viii, f. 84, and t. xiii, f. 108 (not of Berk.).

Bristol! Leigh! Stapleton! Apethorpe!—France.

About the size of a hazel-nut. Globose, regular or variously lobed, or sulcate. Gregarious, or sometimes subcaespitose.

Hymenogaster pallidus, B. and Br. (Fig. 17). Small, rounded, depressed, nearly smooth, white then dirty tan colour, rather soft, within white, then yellow, then pale brown; sterile base obsolete; spores lanceolate, acute, shortly pedicellate, rather rough, 30–36 × 12–14 μ; brown.

Hymenogaster pallidus, B. and Br., Ann. Nat. Hist. xviii, p. 74; Berk., Outl. 296; Tul., Hypog. p. 69; Cke., Hdbk. n. 1058; Quel., Enchirid. 248; Sacc., Syll. vii, p. 173.

(Type in Herb. Berk. n. 4465.)

Cotterstock, Northts.! in a dry fir plantation. Oct. 1865.

This species, which scarcely exceeds in size a horsebean, is nearly allied to the last (*H. vulgaris*), but differs in its more acute spores as well as in colour. (B. and Br.)

Hymenogaster citrinus, Vitt. (Fig. 8). Rotundato-gibbous; shining as if silky, lemon or golden yellow, then rufous-black; same colour inside, substance firm, spores lanceolate, apiculate, rugulose, reddish-brown, opaque, 40 × 17–20 μ.

Hymenogaster citrinus, Vitt., Mon. Tub. 21, t. iii, f. 2, and t. v, f. 9, *b*; Tul., Ann. Sci. Nat. sér. 2, xix, p. 374, pl. xvii, f. 9, 10; Tul., Fung. Hypog. 69, t. i, f. 1, and t. x, f. 3; Berk., Outl. 296; Cke., Hdbk. n. 1057; Fr., Summa Veg. Sc. p. 436; Wint., Kr. Fl. 875; Quel., Enchirid. 248; Sacc., Syll. vii, p. 169.

Splanchnomyces citrinus, Corda, Ic. Fung. vi, t. ix, f. 87.

Exs.—Berk., Brit. Fung. fasc. 4, n. 284; Rab., Fung. Eur. n. 34.

Rudloe! Blaize Castle! Audley End, Wilts!—Europe.

Size variable, from that of a hazel-nut to a walnut, subglobose, variously sulcate and deformed. The yellow veins, subfusiform, rough, dark-coloured spores, the frequently coloured sporophores, and the cheese-like scent, which communicates itself to everything near, are the criterions of this species. When young it is of a greenish yellow, but this soon wears off when rubbed, or exposed to the air. The sporophores occasionally become of a much darker colour than the neighbouring cells, and have a resinous appearance. (M. J. B.)

Hymenogaster olivaceus, Vitt. (Fig. 16). Angularly globose, peridium at first silky, whitish, becoming rufescent when touched; substance whitish at first, then passing through buff to rufous olive, septa white; spores broadly fusiform, mucronate, pedicellate, brown, generally quite smooth, 25–30 × 13–14 μ.

Hymenogaster olivaceus, Vitt., Mon. Tub. p. 24, tab. v, f. 9, *c* (spores); Berk., Ann. Nat. Hist. xiii, p. 348, and xviii, p. 73; Berk., Outl. 296; Cke., Hdbk. 1060; Quel., Enchirid. 249; Wint., Kr. Fl. 876; Sacc. Syll. vii, p. 172.

Exs. — *Hymenogaster populetorum*, Berk., Brit. Fung. no. 304.

In woods. Common in the West of England. Clifton!

Rudloe! Hartham Park! Rushton! Bristol! Apethorpe! Blaize Castle!—Europe.

Variable in size, from that of a hazel-nut to a walnut. Peridium at first white, slightly tinged with lemon-colour; cells at first white, gradually becoming of a dull buff, and then of a reddish grey or brown. Smell like that of *Lactarius theiogalus*. Spores ovate, shortly pedicellate, with an abrupt, elongated, sometimes irregular apex, in general smooth and transparent, and containing 2–3 nuclei, but sometimes slightly rugose, though by no means opaque, as in *H. citrinus*, from which it may be known by its reddish substance, larger cells, more transparent, paler, and smoother spores, which are frequently more abruptly acuminate. (M. J. B., l. c.)

Var. **modestus**, B. and Br.

Spores narrowly fusiform, smooth, pale amber, 25–26 × 8–10 μ.

Hymenogaster olivaceus, var. *modestus*, B. and Br., Ann. Nat. Hist. xviii, p. 74; Tul., Fung. Hypog. 71.

An Hymenogaster occurred at Hartham Park in the autumn of 1845, nearly intermediate between *H. citrinus* and *H. olivaceus*, differing from the former in being of a pale watery brown within, and of a softer texture, with the spores exactly intermediate between those of the two species. The scent was something like that of *H. citrinus*, but not so strong. It was not at all yellow externally, but first white, and then of a watery brown. It grew in a very dry fir-plantation, therefore its watery texture could not arise from situation, especially since *H. citrinus* occurs in much moister situations without any similar appearance. We consider it best for the present to record it as a variety of *H. olivaceus*, differing in scent and in form of the spores. (M. J. B., l. c.)

Hymenogaster tener, Berk. (Figs. 1 and 54). Small, globose, soft, white, silky, substance pale pink, then greyish umber; sterile base conspicuous, white; spores broadly elliptic, with a papillary apex, verruculose or rugulose, ochraceous, 30 × 14–16 μ.

Hymenogaster tener, Berk., Ann. Nat. Hist. xiii, 349, and xviii, 75; Berk., Outl. 296; Tul., Fung. Hypog. p. 72, t. i, f. 4, t. x, f. 1; Cke., Hdbk. n. 1061; Wint., Kr. Fl. 877; Sacc. Syll. vii, p. 174.

Hymenogaster argenteus, Tul., Giorn. Bot. Ital. ann. 1, ii, part 1, p. 55. (Type in Herb. Berk. Kew, n. 4467.)

Exs.—*Hymenogaster lilacinus*, Berk., Brit. Fung. fasc. 4, n. 305 (not *H. lilacinus*, Tul.); Rab., Fung. Eur. 1320.

In woods. Not uncommon. Chudleigh! Hanham! King's Cliffe! Rudloe! Hazlebeech! Bristol! Eltham Grove! Wraxall! Portbury, Somerset!—France.

About the size of a bean or large hazel-nut; globose, soft and tender, white and silky externally; peridium thin, at length dingy, at first white within, but soon acquiring a delicate pink tinge, which, as the spores ripen, changes to an umber grey. Absorbing base white. Very distinct, . . . small like that of *Lactarius theiogalus*. (M. J. B., l. c.)

Hymenogaster Thwaitesii, B. and Br. (Fig. 25). Small, globose, firm, dirty-white, here and there stained; substance brown; spores globose, rather rough, apex with a minute papilla, brown, 11–13 μ diameter.

Hymenogaster Thwaitesii, B. and Br., Ann. Nat. Hist., xviii. p. 75; Berk., Outl. 297; Cke. Hdbk. n. 1062; Tul., Fung. Hypog. 71, t. x, f. 11; Sacc., Syll. vii, p. 174.

Portbury!

This species is proposed as new with the sanction of Messrs. Tulasne, who examined a slice prepared in fluid by Mr. Thwaites. The spores are far more globose than in any other species, and are either quite obtuse or minutely apiculate. The inner membrane of the spores often contracts so as to present a very singular appearance. A few elongated spores are mixed with them, but the normal form is globose; indeed, except the normal form be taken into consideration it would be impossible to draw up technical distinguishing characters of any *Hymenogaster*, as there are always some irregular spores mixed with those which are peculiar to the species,

they are larger than in *H. tener*, but smaller than in *H. decorus*. (B. and Br., l.c.)

Hymenogaster griseus, Vitt. Globose or irregular, pale brown, at first covered with whitish down; cells minute, grey, becoming blackish, spores fusiform, irregularly tuberculose, dark umber brown, 28–32 × 20 μ.

Hymenogaster griseus, Vitt., Monogr. Tub. 23, t. iii. f. xv; Tul., Fung. Hypog. 69 (*not* Tul. in Ann. Sci. Nat. xix. 374); Sacc., Syll. vii, p. 170.

Amongst leaf soil. Epping Forest!—Italy.

The size of a pea or bean, rarely larger, outside whitish at first, septa greyish, as the spores become dark the flesh appears mottled. Odour very pleasant, resembling *Convallaria majalis*. (Vitt., l.c.)

Hymenogaster pusillus, B. and Br. (Fig. 21). Very small, obovate or subdepressed, white; sterile base large; substance dirty white; cells large; spores pallid-rubiginous, broadly elliptic, with a papillary apex, at length rough, 14—16 × 10 μ.

Hymenogaster pusillus, B. and Br., Ann. Nat. Hist. xvii, p. 75; Berk., Outl. 297; Tul., Fung. Hypog. p. 73; Cooke, Hdbk. n. 1063; Sacc., Syll. vii, p. 173. (Type in Herb. Berk. n. 4469.)

On mossy ground in the Wilderness, Rushton, Norths.!

About two lines high, obovate or somewhat depressed, pure white, yellowish brown when dry, and then resembling strongly a specimen of *Sclerotium complanatum*, Tode, nearly smooth; dirty white within, furnished with a large distinct absorbing base. Cavities of the hymenium large for the size of the fungus, clothed sparingly with the rust-coloured spores. Sporophores clavate, frequently forked or irregular, having two spores on rather long spicules. Spores short, minute, broadly elliptic, at first smooth, at length rather rough, obtusely apiculate. This species, which has no particular odour, has at present occurred very sparingly. Its

nearest ally is *H. tener*, but the cavities of the hymenium are larger; it is almost without scent, and there is not the slightest tendency to become black in drying. There is little difference in the size or form of the spores. (B. and Br.)

Pompholyx sapidum, Corda. Recorded from near Chichester, but the specimen is evidently a species of *Scleroderma*, probably *S. geaster*.

SCLERODERMEAE.

Peridium thick, opening at the apex in an irregular manner, gleba containing numerous cavities, tramal plates disappearing or persistent, and enclosing peridiola, capillitium absent or scanty. Peridium appearing above the ground when mature.

Allied to the Hymenogastreae, but distinguished by the presence of a well-defined base to the peridium, which not unfrequently becomes elongated into a stout stem-like base; and by the peridia appearing above the surface when mature.

SCLERODERMA, Pers. (emended).

Peridium firm, cortex persistent in the form of warts or granules, indehiscent or splitting in a stellate manner at the apex; gleba with the walls of the trama springing from every part of the peridium, subpersistent; spores globose, verrucose.

Scleroderma, Pers., Syn. p. 159; Fries, Syst. Myc. iii, p. 44; Sacc., Syll. vii, p. 134 (in part).

The genus is closely related to *Polysaccum*, from which it differs in the trama becoming broken up when the spores are mature, whereas in the latter the trama is persistent, especially towards the base, and forms the so-called peridiola.

Scleroderma vulgare, Fr. (Fig. 45). Subsessile, often caespitose, irregularly lobed or depressed; peridium thick, corky, thickened and convex internally at the base, white, becoming pinkish when cut, externally verrucose; trama white; spores in the mass blackish with a tinge of purple, globose, coarsely warted, 9–11 μ diam.

Scleroderma vulgare, Fries, Syst. Myc. iii, p. 46; Fl. Dan. t. 1969, f. 2: Berk., Eng. Fl. v, p. 305; Berk., Outl. p. 303, pl. xv, f. 4 (with *Boletus parasiticus* growing upon it); Cooke, Hdbk. n. 1090, fig. 116; Hussey, i, t. xvii, f. 1; Wint., Kr. Fl. p. 888; Sacc., Syll. vii, p. 134.

Lycoperdon cervinum, Bolt., Fung. t. 116.

Lycoperdon aurantiacum, Bull., p. 158, t. 270; Sow., t. 268.

Exs.—Oudemans, Fung. Néerl. 245; Syd., Myc. March. 107; Roum., Fung. Gal. 715; Rab., Fung. Eur. 243; Cooke, Fung. Brit. 417; Sacc., Myc. Ven. 1412; Fuckel, Fung. Rhen. 1253 and 2483; Thum., Fung. Austr. 334; Herbarium Mac-Owanianum 1454, under name of *Melanogaster Owanianum*, Kalchb.

In open places under trees, etc. Common. New Forest! Kew! Hereford! Lincoln! Scarborough! Carlisle! Guernsey! —United States; Madeira; S. Africa; S. Australia; Tasmania; New Zealand; Perak; Nova Zembla.

From 1 to 3 inches diameter, usually depressed, so that a section of the gleba is more or less reniform; gleba blackish with purple tinge, and just before maturity marbled with white lines corresponding to the trama; peridium externally variable, usually pale with yellow shades, sometimes bright brown, in some specimens covered with large squarrose scales, in others, adnate warts, which in the brown form are often very minute. The sporophores usually originate from a dense mass of cord-like mycelium, which persists as a rooting base.

Scleroderma verrucosum, Pers. (Fig. 47). Peridium subglobose, thin and fragile above, covered with minute warts, continued below into a more or less elongated stem-like base; mass of spores umber, lines of trama whitish; spores globose, warted, 10–13 μ diam.

Sclcroderma verrucosum, Pers., Syn. p. 154; Grev., Scot. Cr. Fl. t. 48; Hussey, t. 17, f. 2; Berk., Outl. p. 303; Berk., Eng. Fl. p. 306; Cke., Hdbk. n. 1092; Quel., Enchirid. p. 243; Wint., Kr. Fl. p. 889; Sacc. Syll. vii, p. 130.

Lycoperdon defossum, Sow., t. 311.

Lycoperdon verrucosum, Bull., p. 157, t. 24.

Exs.—Rab., Wint., Fung. Eur. 3141; Flora Exs. Austro-Hungarica, 1559; Fuckel, Fung. Rhen. 1254; Oudem., Fung. Néerl. 120; Desm., Cr. Fr. sér. 1, 467; Syd., Myc. March. 451.

On sandy ground under bushes, etc. Lyndhurst! Kew! Hampstead! Hereford! Scarborough! Carlisle!—United States; S. Africa; Thibet; Australia; New Zealand.

Peridium 1–3 in. across, ochraceous or dingy brown, covered with minute warts; stem-like base sometimes an inch or more in length, thick and lacunose, sometimes much shorter, when it somewhat resembles externally *S. vulgare*, from which it is distinguished by the thin and fragile upper portion of the peridium, and the absence of purple tinge of the immature gleba.

Scleroderma bovista, Fr. (Fig. 36). Subsessile, irregular, peridium thin, pliant, the nearly smooth cortex inclined to break away in patches; trama floccose, yellow, mass of spores olive-brown, spores globose verrucose, 10–13 μ diam.

Scleroderma bovista, Fries, Syst. Myc. iii, p. 48; Berk., Eng. Flor. 306; Berk., Outl. p. 303; Cke., Hdbk. n. 1091; Wint., Kr. Fl. p. 889; Karst., Myc. Fen. p. 363; Quel., Enchirid. p. 243; Sacc., Syll. vii, p. 135.

Lycoperdon defossum, Batsch, f. 229.

Exs.—Thum., Myc. Univ. 607; Ellis, N. Amer. Fung. 24.

Sandy ground amongst bushes, etc. Loughton, Essex! Castle Howard, Yorks.! Aberdeen!—United States; Natal; Sikkim.

From 1–2 in. across, often irregular, furnished with a mass of mycelium forming a branched rooting base. Recognised by the thin peridium, olive-brown spores, and yellow trama, which becomes floccose, and persists as an imperfect capillitium consisting of septate threads with clamp-connections.

Scleroderma geaster, Fries (Fig. 35). Globose, sessile, peridium thick, almost smooth, splitting in a stellate manner

at the apex, lobes subequal, mass of spores umber with a purple tinge, trama whitish, spores globose, coarsely warted 12–16 μ diam.

Scleroderma geaster, Fries, Syst. Myc. iii, p. 46; Quel., Enchirid. p. 243; Sacc., Syll. vii, p. 138.

Exs.—Thum., Myc. Univ. 608; Rav., Fung. Carol. 4.

In sandy places. Rare. Hereford!—Europe; United States.

Readily recognised by the thick peridium splitting at the apex in a stellate manner when mature.

POLYSACCUM, D. C.

Peridium irregularly globose, corky, attenuated downwards into a more or less elongated stem-like base; gleba consisting of numerous cavities containing peridiola. Dehiscing by an irregular rupture at apex of peridium.

Polysaccum, D. C., in Desp. and Rapp. Voy. Bot. i, p. 8; Fl. Fr., v. p. 103; Sacc., Syll. vii, p. 146.

Pisolithus, A. and S.; *Pisocarpium*, Lk.; *Polyera*, Ficin.; *Scleroderma* sp. of various old authors.

Related to *Scleroderma*, but readily distinguished by the presence of distinct peridiola.

Polysaccum pisocarpium, Fr. (Fig. 53). Peridium subglobose, passing downwards into a short stem-like base. Peridiola large, irregular, angular, 4–5 × 2–3 mm., yellow; spores spherical, warted, coffee-colour, 9–13 μ.

Polysaccum pisocarpium, Fr.; Krombh., Heft 8, p. 20, taf. lx, f. 9, 10. Dietr., Deutsch. Fl. (Schwämme), pl. 118; Winter, Krypt. Fl. p. 890; Mass., Rev. *Polysaccum*, Grev. v, 16, p. 28; Sacc., Syll. vii, p. 148.

Polysaccum acaule, D. C., Rapp. de Voy. ii, p. 80; Fl. Fr. vi, p. 103.

Polysaccum arenarium, Corda, Ic. Fung. ii, pp. 24, 25, tab. xii, f. 91.

Polysaccum olivaceum, Fr., S. M. iii, 54.

Polysaccum uliferum, Secr., Myc. Suisse, iii, p. 373.

Pisolithus arenarius, Alb. et Schw., Conspect. Fung. p. 82, tab. i, f. 3.

Pisocarpium arenarium, Nees, Syst. i, p. 27.

Lycoperdon capsuliferum, Sow., Eng. Fung. pl. 425.

Exs.—Rav., Fung. Amer. 470; Roum., Fung. Gall. 1311; Welw., Crypt. Lusitana, 60.

On the ground in sandy places. England.—Europe; N America; Australia; New Zealand.

Peridium smooth, even, or rather tuberculose, fragile, dehiscing irregularly, reddish-brown, tinged olive, 1–3 in. diam. Sowerby's plant is undoubtedly this species, and was at the time correctly referred to the figure of Albertini and Schweinitz, Consp. Fung. t. f. 3; which in turn is synonymous with *P. pisocarpium*.

NIDULARIEAE.

Spores produced in the interior of one or more indehiscent, globose, or compressed peridiola contained within a distinct peridium.

Nidulariaceae, Fries, Syst. Myc. ii, p. 296; Tul., Mon. Nid. Ann. Sci. Nat. sér. 3, i, p. 64 (in part).

The genus *Sphaerobolus* is not included by Tulasne in the Nidularieae; it is true that it differs in the peculiar arrangement for ejecting the solitary peridiolum from the peridium, but the most pronounced morphological feature of the group is to be found in the complete differentiation of peridiola from the hyphae of the gleba, and in this peculiarity *Sphaerobolus* agrees with *Cyathus*, *Crucibulum*, and *Nidularia*. The affinities of *Thelebolus*, the development of which is not known, is uncertain, but the general structure when mature justifies its being placed in the present order.

CYATHUS, Haller.

Peridium composed of three distinct, closely connected layers, apex, at first closed by a white membrane (epiphragm), becoming broadly open; peridiola compressed, umbilicate, attached to inner wall of peridium by an elastic cord (funiculus).

Cyathus, Haller, Helv. v, p 127; Tul., Ann. Sc. Nat. sér. 3 i, p. 65; Sacc., Syll. vii, p. 32.

Nidularia, Bull., Champ. 60; Fries, Syst. Myc. ii, p. 297.

The genus cannot be confounded with any other if attention is paid to the triple structure of the wall of the peridium and the umbilicate peridiola.

Cyathus striatus, Hoffm. (Fig. 48). Obconic, truncate at base and apex, at first closed with a pale epiphragm, becoming broadly open; polished, lead-coloured and striate within, externally hirto-tomentose, ferruginous; peridiola sub-circular, compressed, umbilicate, about 2 mm. across, spores elliptic-oblong, colourless, smooth, 18–22 × 10 μ.

Cyathus striatus, Hoffm., Veg. Crypt. (1790), p. 33. t. viii, f. 3; Pers., Syn. p. 237; Nees, Syst. 140, t. xiii, f. 132; D. C., Fl. Fr. ii, 269; Tul., Monog. Nid., Ann. Sci. Nat. sér. 3, i. p. 67, pl. 3, pl. 4, f. 1–3, pl. 8, f. 1–12; Berk., Outl. 312, pl. 2, f. 3; (the striations are represented on the outside of the peridium instead of inside); Cooke, Hdbk. n. 1199; Sacc., Syll. vii, 97; Karst., Myc. Fenn. 365; Wint., Kr. Fl. 920.

Nidularia striata, Sow., t. 29; Fr., Syst. Myc. iii, p. 298.

Peziza hirsuta, Batsch, Elench. Fung. 127.

Peziza striata, Huds., Fl. Angl. 634; Bolt., Fung. Halifax, 102, t. cii, f. 2.

Exs.—Holl, Schmit and Kunze, Deutschl. Schw. xcv; Jack, Leiner u. Sitzenberger, Krypt. Badens, 50; Flor. Gall. et Germ. 800; Flor. Exs. Austr.-Hung. 1558; Cke., Fung. Brit. ed. 2, 616; Sydow, Myc. March. 54; Roum., Fung. Sel. Gall. (Rel. Moug.) 210; Klotzsch, Herb. Myc. (Rab.) 135; Cke., Fung. Brit. 311; Fuckel, Fung. Rhen. 1247; Roum., Fung. Gall. 2617; Ellis, N. Amer. Fung. 729; Thum., Fung. Austr. 1215; Karst., Fung. Fenn. 2; Sacc., Myc. Ven. 39; Moug. and Nest., 283; Desm., Cr. Fr. (sér. 1) 764; Kunze, Fung. Sel. 12; Berk., Brit. Fung. 259.

On twigs, wood, fir-cones, etc. Common. Bristol! Wrotham! Laxton, Norths.! Kew! Castle Howard, Yorks.! Scar-

borough! Carlisle!—N. America; Jamacia; British Guiana; East Indies.

Fasciculate. From ½–⅔ in. high, the margin at first incurved, then after the disappearance of the epiphragm spreading and exposing the shining fluted inner surface of the peridium. Peridiola when moist more or less circular in outline and biconvex, with a marked depression or umbilicus in the centre of one side, from which originates a long, thin, elastic thread or funiculus. When dry the peridiola are more or less trigonous in outline.

Cyathus vernicosus, D. C. (Figs. 49–51). Campanulate, mouth broadly open, undulate, tapering downwards to a narrow base, inside smooth, even, lead-coloured or brownish, outside ochraceous or greyish, minutely silky, becoming smooth; peridiola circular, biconvex, umbilicate, blackish, shining, from 3–4 mm. across; spores broadly elliptical, colourless, 12–14 × 10 μ.

Cyathus vernicosus, D. C., Fl. Fr. ii, 270; Duby, Bot. Gall. ii, 865; Tul., Mon. Nid., Ann. Sci. Nat. sér. 3, i, p. 81, pl. v, f. 14–23; Berk., Outl. 312, pl. 21, f. 1; Cooke, Hdbk. n. 1199; Sacc., Syll. vii, n. 110; Wint., Kr. Fl. 920.

Cyathus laevis, Hoffm., Veg. Crypt. p. 31, t. 8, f. 2.

Cyathus Olla, Pers., Syn. Fung. 237; Nees, Syst. 140, t. 13, f. 133 *B.*

Cyathus campanulatus, Corda, Anl. t. D. f. 42 (19–23).

Nidularia vernicosa, Bull., Champ. i, p. 164, pl. 448, f. 1.

Nidularia campanulata, Withering, Bot. Arr. iii, 445; Sow., t. 26; Fr., Syst. Myc. ii, 298.

Peziza Olla, Batsch, Elench. Fung. 127.

Peziza lentifera, Huds., Fl. Angl. 633; Bolt., Fung. Halifax, iii, p. 102, t. 102, f. 1.

Exs.—Kunze, Fung. Sel. 13: Jack, Leiner u. Sitzenberger, Krypt. Badens, 332; Rav., Fung. Car. 3; Desm., Cr. Fr. sér. i, 765; Rav., Fung. Amer. 473; Cke., Brit. Fung. 312; Sacc., Myc. Ven. 109; Crypt. Lusit. 37; Klotzsch, Myc. (Rab.) 247;

Roum., Fung. Sel. Gall. (Reliq. Moug.) 110; Roum., Fung. Gall. 2616; Ellis, N. Amer. 1308; Karst., Fung. Fenn. 989; Fuckel, Fung. Rhen. 1246; Sydow, Myc. March. 215; Oudem., Fung. Néerl. 242; Berk., Brit. Fung. 258; Moug. and Nest., Stirp. Crypt. 182.; Ex. Herb. Bot. Belg. (Westendorp) 282; Thum., Myc. Univ. 413.

On the ground, especially in stubble fields, not uncommon. Falmouth! Cambridge! Tansor, Northsh.! Castle Howard, Yorks.! Carlisle! Coed Coch!—U. States; S. Australia; New Zealand; Africa; Teneriffe; Chili.

Readily distinguished from *C. striatus* by the absence of the internal flutings, and the smooth outside of the peridium. The peridiola are large, black, and shining, and the funiculus white. Gregarious; about ½ in. high.

Var. **agrestis.**

Smaller, subhemispherical, margin erect. Tul., Mon. Nid. Ann. Sci. Nat., sér. 3, 1, p. 83.

Cyathus agrestis, Fr., Syst. Myc. ii, 298.

On chips. Bulmer, Yorks.!

CRUCIBULUM, Tul.

Peridium consisting of a double, thick, felt-like membrane, which is at first continuous over the apex as a flat epiphragm; peridiola numerous, compressed, attached to a long cord, which originates from a nipple-like tubercle situated centrally on one of the flattened surfaces.

Crucibulum, Tul., Mon. Nid. Ann. Sci. Nat. sér. 3, i, p. 89; Sacc., Syll. vii, p. 43.

Cyathus, Pers., Grev.

Nidularia, Sow., Fries.

Cannot be confounded with any other genus if attention is paid to the peculiar structure of the peridiola.

Crucibulum vulgare, Tul. (Fig. 52). Peridium thick, dirty cinnamon or greyish, externally minutely tomentose, smooth

and shining inside: peridiola circular, biconvex, pale ochraceous, becoming whitish, 1·5–2 mm. across; spores elliptic oblong, smooth, colourless, 10 × 5–6 μ.

Crucibulum vulgare, Tul., Mon. Nid., Ann. Sci. Nat., sér. 3, i, p. 90, pl. 6, f. 9–24, pl. 7, f. 1, pl. 8, f. 13–17; Berk., Outl. p. 312, pl. 2, f. 1; Cooke, Hdbk. n. 1200, f. 143; Karst., Myc. Fen. 357; Wint., Kr. Fl. 918; Sacc., Syll. vii, p. 43.

Cyathus Crucibulum, Pers., Syn. 238; Nees, Syst. s. 140, t. 13, f. 133; Grev., Scot. Cr. Fl. t. 34.

Cyathus laevis, D. C., Fl. Fr. ii, 269.

Cyathus cylindricus, Wild., Fl. Berol. prodr. p. 399.

Cyathus crucibiliformis, Hoffm., Veg. Crypt. 29, t. 8, f. 1.

Peziza laevis, Huds., Fl. Angl. ii, p. 634.

Nidularia laevis, Bull., Champ. i, p. 164, t. 448, f. ii; With., Arr. iii, 446; Sibth., Fl. Oxon. n. 1112, p. 393; Sow., t. 30; Holmsk., Fl. Dan. ii, p. 1, t. i.

Pezize à lentilles, Bull., Champ. pl. 40, f. b, c.

Exs.—Cke., Fung. Brit. ser, 2, 516; Oudem., Fung. Néerl. 243; Sydow, Myc. March. 106; Roum., Fung. Sel. Gall. 477; Klotzsch, Herb. Myc. 136; Sacc., Myc. Ven. 38; Fuckel, Fung. Rhen. 1248; Thum., Fung. Austr. 1214; Karst., Fung. Fenn. 934 and 77; Ellis, N. Amer. Fung. 728; Berk., Brit. Fung. 167; Westendorp, Herb. Crypt. Belg. 481; Rav., Fung. Amer. 139; Moug. and Nest., 776; Cke., Fung. Brit. 419; Desm., Cr. Fr. sér. 1, 766.

On branches, twigs, etc., not uncommon. Apethorpe! Wothorpe! Coed Coch! Castle Howard, Yorks.! Glamis, N.B.!—Europe; N. Africa; Patagonia; United States; Australia; New Zealand.

Variable in size, becoming broadly open, aud from 5–8 mm. or sometimes 1 cm. across. Gregarious, sometimes crowded.

NIDULARIA, Tul.

Peridium consisting of a single membrane, at first closed, then opening by a more or less regular mouth or irregularly

ruptured. Peridiola numerous, enveloped in mucus, not attached to inside of peridium by a funiculus.

Nidularia, Tul., Mon. Nid. Ann. Sci. Nat. sér. 3, i, p. 92; Fries, S. M. (in part); Sacc., Syll. vii, p. 28.

Granularia, Roth.

Readily distinguished from the allied genera *Cyathus* and *Crucibulum* by the peridiola being free in the peridium, and not attached to the wall by an elastic cord or funiculus.

Nidularia pisiformis, Tul. (Fig. 37). Gregarious or solitary; sessile, not rooting, cinnamon or brownish, strigose or only slightly hairy, tuberculose above, splitting irregularly; peridiola sub-rotund, biconvex, brown, smooth, shining, wrinkled when dry, about 2 mm. across; spores colourless, typically broadly obovate, sometimes subglobose or elliptical, 7–8 × 8–9 μ.

Nidularia pisiformis, Tul., Monog. des Nidular., Ann. Sci. Nat. sér. 3, i, p. 100; Curr., Linn. Trans. xxiv, t. 25, f. 4–6 and 21–22; Cke., Hdbk. n. 1201; Sacc., Syll. vii, p. 32.

Granularia pisiformis, Roth, in Ust. Ann. Bot. Band i, st. i, s. 6, t. i, f. 1.

On chips, leaves, and on soil. St. George's Hill, Weybridge! Powerscourt!

Peridia 4–6 mm. across, sessile, seated on a broad base, sometimes flattened above; peridiola compacted into a firm mass by the mucus originating from disintegration of the hypha. The species is rare everywhere, and was not seen by Tulasne, who consequently could add nothing to the imperfect description given by Roth, hence it must ever remain doubtful as to whether we have the true species in view.

Var. **Broomei**, n. var.

Spores narrowly elliptical, with a thick hyaline epispore, 10 × 4–5 μ.

Nidularia pisiformis, Tul.

Exs.—Rab., Fung. Eur. 1328.

On pine wood, Batheaston!

Externally resembling the typical form, but differing in the spores.

Nidularia Berkeleyii, Mass., n. sp. (Fig. 38). Subglobose, becoming broadly open; peridium thick, felt-like, externally hirto-tomentose, bright cinnamon, inside same colour, velvety; peridiola numerous (40–50), circular, biconvex, about 2 mm. diameter, bright brown, smooth, shining, much wrinkled when dry; spores elliptical, 9–10 x 5–6 μ, smooth, at first colourless, then becoming pale brownish olive.

On wood, twigs, etc., collected abundantly in Powerscourt deer park by the Rev. M. J. Berkeley, Sept. 1867, and referred to *Nidularia farcta*, from which it differs in the peridium being bright cinnamon outside and velvety inside, and in the entire absence from the earliest stage of the long rooting mycelium.

Peridium 5–7 mm. broad and high, with not a trace of cord-like roots at base, solitary, or 2–3 together, margin thick, mass of peridiola firmly agglutinated together by mucus.

Nidularia confluens, Fr. (Fig. 81). Not rooting, aggregated or subconfluent, peridia subsphaerical, thin, villose, irregularly ruptured, whitish; peridiola numerous, orbicular, compressed, glabrous, about 1·5 mm. across, becoming corrugated when dry; spores broadly elliptical, smooth, colourless, 8 x 10 x 6–7 μ.

Nidularia confluens, Fries et Nordh., Symb. Gast. p. 3; Sacc., Syll. vii, p. 29; Tul., Mon. Nid. p. 96.

Nidularia farcta (confluens), Fries, Syst. Myc. ii, 301.

On chips and amongst leaves, rarely on the ground. Britain. —Europe.

This species has been recorded as British. I have seen no British specimens, and the spores are drawn from an authentic specimen sent by Fries to Berkeley. Crowded and often irregular, villose, rather large.

Nidularia dentata, With. 'Turban-shaped. Smaller than a hempseed. Colour pale buff; rather woolly; five segments or teeth at the edge, broad, spear-shaped, regular.

Membrane tough, whitish. Seeds or capsules reddish brown. Several growing together on rotten twigs near the grate at Edgbaston Pool. Sept.'

Nidularia dentata, With., Arrang. of Brit. Pl. (3rd ed.) iv, p. 357 ; Tul., Mon. Nid. p. 96 ; Sacc., Syll. vii, p. 31.

The above species, which has not been met with since Withering's time, appears to be distinct, and we fail to see why it has been excluded from British Mycological works for so long. It may prove to be a *Sphaerobolus*.

SPHAEROBOLUS, Tode.

Peridium consisting of two layers, the inner at length extruded elastically, and ejecting the single peridiolum.

Sphaerobolus, Tode, Meckl. i, p. 43 ; Fr. S. M. ii, p. 309.

Carpobolus, Mich. gen. 221.

Lycoperdon, Linn.

Characterised by the solitary peridiolum, and the elastic inner layer of the peridium.

Sphaerobolus stellatus, Tode (Fig. 55). Crowded or rarely solitary ; peridium pale yellow or whitish, externally minutely tomentose ; mouth stellato-dentate ; peridiolum broadly elliptical ; spores elliptic-oblong, or obovate, smooth, colourless, 10 × 5 μ.

Sphaerobolus stellatus, Tode, Meckl. i, p. 45 ; Pers., Syn. 115 ; Fries, Symb. Gast. p. 1 ; Fries, Syst. Myc. ii, p. 310 ; Berk., Eng. Flor. v, p. 231 ; Berk., Outl. p. 312, pl. 21, f. 2 ; Cooke, Hdbk. n. 1202, f. 145 ; Tul., Fung. Hypog. t. 21, f. 11 ; Corda, Ic. Fung. v. f. 48 ; Quel., Enchirid. 234 ; Wint., Kr. Fl. 921 ; Karst., Myc. Fenn. 358.

Lycoperdon carpobolus, Linn., Sp. pl. ii, p. 1654 ; Batsch, Elench. 153 ; Sow., t. 22.

Exs.—Rab., Fung. Eur. 36 and 2420 ; Cke., Fung. Brit. 425 ; Roum., Fung. Gal. 2718 ; Karst., Fung. Fenn. 176 ; Desm., Cr. Fr. sér. 1, 2026 ; Fuck., Fung. Rhen. 1245 ; Syd., Myc. March. 110 ; Lib., Pl. Cr. Ard. 337.

On wood, sawdust, twigs, and not uncommon. Maidstone !

Kew! Hereford! Colleyweston! Derby! Scarborough! Carlisle! Coed Coch! Aboyne! Edinburgh!—Europe; N. America; S. Africa; Australia; N. Zealand; Tasmania; Ceylon.

Plants at first connected by a web, at length smooth, subglobose, yellowish; outer peridium consisting of two substances, lined by the inner peridium, which is quite distinct and separated by some moisture, white, pellucid, and shining, at length both split together in a stellate manner, and the inner becomes suddenly inverted, while in general it still remains attached by the apices of the stellate margin, and the sporangium is shot forth to a considerable distance. Sporidia $\frac{1}{1000}$ in. long, elliptic, or curved and irregular. The rays of the outer peridium are orange within (M. J. B.).

Peridia about 2 mm. across.

THELEBOLUS, Tode.

Peridium homogeneous, sessile on a broad base, subrotund, then urceolate-ventricose, peridiolum solitary, protruding from the apex of the peridium.

Thelebolus, Tode, Meckl. i, p. 41; Sacc., Syll. vii, p. 44.

Allied to *Sphaerobolus*, from which it differs in the peridium consisting of a single layer.

Thelebolus terrestris, A. and S. (Fig. 57). Peridium at first hemispherical, urceolato-ventricose, saffron yellow, seated on a dense tomentose subiculum, peridiolum spherical, solitary; spores elliptic-oblong, colourless, 10–12 × 5–6 μ.

Thelebolus terrestris, Alb. and Schw., Cons. Fung. p. 71, t. ii, f. 4; Cke., Hdbk. n. 1203, f. 146; Corda, Anl. t. D, f. 44, nos. 9–11; Sacc., Syll. vii, p. 44.

Exs.—Klotzsch, Herb. Myc. (Rab.) 718; Fuckel, Fung. Rhen. 643.

On the ground, on rotten wood, or running over leaves, etc. Richmond, Yorks.!—Europe.

Forming dense felty patches of a yellowish colour, 1–2 in. broad. Peridia crowded, emerging from the subiculum, from 1–2 mm. diameter.

LYCOPERDEAE.

Peridium double, rarely single, spores forming a powdery mass when mature and mixed with a well-developed capillitium.

Trichogastres, Fr., Syst. Myc. iii, p. 3; Berk., Outl. p. 298 (in part).

Diplodermeae, Sacc., Syll. vii, p. 60 (in part).

BOVISTA, Dill.

Peridium double, external layer (cortex) fragile, deciduous, rarely remaining in the form of adnate warts, inner layer smooth, dehiscing by a definite or irregularly torn apical orifice; capillitium dense, threads usually much branched, sometimes sparsely septate, smooth, tips tapering; sterile basal stratum absent ; spores globose or elliptical; epispore rough or smooth.

Bovista, Dill., Pers., Disp. p. 6; Link, Diss. i, p. 32; Fries, Syst. Orb. i, p. 138; Fries, Syst. Myc. iii, p. 21 (all in part); Mass., Rev. Bovista, p. 1; Sacc., Syll. vii, p. 96 (in part).

Lycoperdon, Vitt., Mon. Lycop. (in part).

Globaria, Quel., Champ. Jur. et Vosg. p. 361 (in part).

For remarks on the affinities of *Bovista* see *Lycoperdon*.

A. *Spores Elliptical.*.

Bovista ovalispora, Cke. and Mass. (Fig. 62). Subglobose, sessile, cortex whitish or ochraceous, breaking away in patches above, subpersistent towards the base; peridium thin, flaccid, smooth, dull lead-colour, dehiscing by an apical irregular rupture; capillitium and spores umber in the mass; threads 12-16 μ at thickest part, much and vaguely branched, tapering to long slender tips, walls thick, dirty umber, spores elliptical, brownish umber, with a narrow hyaline border, pedicels long, stout hyaline, 6×4–$5\ \mu$.

Bovista ovalispora, Cke. and Mass., Grev. xvi, p. 46; Mass., Revis. Bovista, n. 34; (Type in Herb. Kew).

On the ground. Kew Gardens!—Nelson (New Zealand); Carolina (U. S. A.).

Differs from *B. plumbea* in its larger size (2 in. and more across), broadly elliptical spores with a hyaline border, and much thinner cortex; and from *B. nigrescens* in the elliptical spores and absence of purple tinge in mass of capillitium and spores.

B. *Spores Globose.*

Bovista nigrescens, Pers. (Fig. 39). Subglobose; cortex papery, whitish, soon breaking away, peridium thin, tough, shining, blackish umber, dehiscing by an irregular apical orifice; mass of spores and capillitium umber with a decided purple tinge; threads 12–18 μ at thickest part, thick-walled bright brown, much branched, tips tapering; spores same colour, globose, smooth, pedicellate, 5–6 μ diameter.

Bovista nigrescens, Pers., Syn. p. 136; Fries, Syst. Myc. iii, p. 23; Karst., Myc. Fenn. (Basidiomycetes) p. 359; Berk., Engl. Flor. v, p. 302; Berk. Outl. Fung. p. 301, pl. 20, f. 5; Cke., Hdbk. p. 371; Mass., Revis. Gen. Bovista, n. 15; Sacc., Syll. vii, p. 99; Wint., Kr. Fl. 907.

Lycoperdon nigrescens, Vitt., Mon. Lyc. 176.

Lycoperdon globosum, Bolt., t. 118; Withering, iv, p. 350.

Lycoperdon bovista, Sow., t. 331.

Lycoperdon ardosiacum, Sowerby, Herb., from specimen now in Herb. Berk.

Globaria nigrescens, Quel., Enchirid. p. 240.

Exs.—Desm., Crypt. Fr., sér. 1, 527; Fuckel, Fung. Rhen. 1884; Karsten, Fung. Fenn. 117; Cke., Fung. Brit. 521.

Dry pastures and heathy places. From 1–2 in. across.

Bovista plumbea, Pers. (Fig. 63). Globose; cortex thin, whitish, persistent towards the base; peridium tough, thin, lead-coloured, dehiscing by a small, irregular mouth; mass of spores and capillitium umber-brown; threads thick-walled, stout, 12–16 μ at thickest part, brown, much branched; spores paler, sub-globose, smooth, generally pedicellate, 5–6 μ diameter.

Bovista plumbea, Pers., Syn. 137, t. 3, f. 1; Fries,

Syst. Myc. iii, p. 24; Berk., Engl. Flor. v, p. 302; Berk., Outl. p. 301, pl. 20, f. 6; Cke., Hdbk. p. 372; Karst., Myc. Fenn. (Basid.) p. 360; Corda, Ic. Fung. v, f. 47; Mich., t. 97, f. 6; Mass., Revis. Gen. Bovista, n. 16; Sacc., Syll. vii, p. 96; Wint., Kr. Fl. 907.

Lycoperdon ardosiacum, Bull., t. 192, A, B; With., iv, p. 351.

Lycoperdon plumbeum, Vitt., Mon. Lyc. p. 174.

Globaria plumbea, Quel., Enchirid. 240.

Exs.—Klotzsch, Fung. Germ 57; Oudem., Fung. Néerl. 117; Kx., Rech. Fl. Crypt. Fland. 1261; Fuckel, Fung. Rhen. 1262; Klotzsch, Herb. Myc. 143.

Dry grassy and heathy places.

Too closely allied to *B. nigrescens*, the main distinctive features being the usually smaller size, and absence of a purple tinge in the mass of spores and capillitium. About 1 in. across.

Bovista olivacea, Cke. and Mass. (Fig. 67). Globose, cortex very thin and fugacious, peridium thick, soft, becoming brittle and breaking away in patches, white or ochraceous; mass of spores and dense capillitium citron, then olive; threads thin, pale, flaccid, mostly simple; spores globose, smooth, pale yellow, sometimes pedicellate, 5 μ diameter.

Bovista olivacea, Cke. and Mass., Grev. xvi, p. 77; Mass., Revis. Gen. Bovista, n. 17. (Type in Herb. Kew.)

On the ground. Durdham Down, near Bristol!—Winmera, Victoria.

Peridium 1½–2 in. across, cortex thin, evanescent, peridium thick, at first soft and pliant like chamois leather, becoming dry and brittle and breaking away in patches upwards. Externally resembling small forms of *Lycoperdon bovista*, L., but there is no trace of a sterile basal stratum.

Bovista ammophila, Lev. (Fig. 40). Broadly obovate, plicate below and passing into a long, stout, tapering root; cortex whitish, broken up into tomentose warts, peridium thin, pallid, dehiscing by a small, irregularly torn apical mouth; mass of spores and capillitium olive; threads branched,

thick-walled, olive; spores globose, smooth, pale, pedicellate, 5–6 μ diameter.

Bovista ammophila, Lev., Ann.Sci. Nat sér. 3, ix, p. 129, pl. 9, f. 5; B. and Br., Ann. Nat. Hist. n. 1033; Cooke, Hdbk. p. 372; Mass., Revis. Bovist. n. 20; Sacc., Syll. vii, p. 98. (Specimen determined by Rev M. J. Berkeley, in Herb. Berk. n. 4594.)

On the ground in sandy places. Cefu Meinadoch, Denbighshire!—France.

From 1–1½ in. high.

Bovista cepaeforme (Bull.), Mass. (Fig. 72). Sessile, subglobose, peridium papyraceous, cortex white, minutely furfuraceous, breaking away in patches, dehiscing by a minute, torn mouth; root long, cord-like. Threads of capillitium much branched, axils rounded, spores bright citrin, smooth, globose, often with a short, thick pedicel, 4 μ diameter.

Lycoperdon cepaeforme, Bull., t. 403, f. 2 (upper row); Wint., Cr. Fl. p. 902; Mass., Mon. Lyc. n. 100.

Lycoperdon pratense, Pers., Syn. Fung. 143.

Lycoperdon pusillum, Berk., Engl. Flor. v, p. 304 (in part).

Globularia furfuracea, Quel., Champ. Jur. et Vosg. 361; Quel., Enchirid. 241.

England!—France,

Vittadini's figure of *L. plumbeum*, t. 33, f. 1, Fung. Mang., very much resembles Bulliard's figure, but in the former the spores are said to be 'fusco-purpurea.' About 1 in. across.

Bovista pusilla (Fr.), De Toni (Fig. 59). Peridium subglobose, sometimes slightly attenuated at the base, flaccid, persistent, with minute adpressed scurfy squamules, becoming smooth, dehiscing by a minute irregular apical pore, pale olivaceous ochre, furnished with a long, slender, tapering root, capillitium dense, threads much branched, axils rounded, lax, flexuous; spores olivaceous-ochre, globose, smooth, about 4 μ diam.

Lycoperdon pusillum, Fries, Syst. Myc. iii, 33; Berk.,

Engl. Flora, 304 (in part); Bolt., t. 117, f. C.; Cke., Hdbk. n. 1086; Karst., Myc. Fenn. iii. 360; Batsch, Elench. f., 228, var.; Schaeff., Ic. t. 294; Bull., t. 435, f. 2; Wint., Kr. Fl, 898; Mass., Mon. Lyc. n. 106.

Globularia pusilla, Quel., Champ. Jur. et Vosg. ii, t. 3, f. 7; Quel., Enchirid. 239.

Exs.—Cke., Fung. Brit. 611; Klotzsch, Herb. Myc. 513; Fuckel, Fung. Rhen. 1261; Thum., Fung. Austr. 222; Rav., Fung. Amer. 138.

In pastures and on hedge banks. Kew! Castle Howard, Yorks.! Norfolk! Conway! Aberdeen!—Europe; N. America; Bonin Islands; Lower Pegu; Hong Kong; Whampoa; East Nepal; Rio Janeiro; Ceylon; New Zealand; Melbourne; Somerset East (Africa); King George's Sound.

The smallest of British puff balls, varying fro m -⅛ in. diameter.

LYCOPERDON, Tournef. (emended).

Peridium double, external layer (cortex) becoming broken up into subpersistent warts or spines, inner layer smooth, dehiscing by a small apical aperture, or the whole of the upper portion evanescent. Capillitium dense, threads usually branched, with tapering ends, smooth; sterile basal stratum present; spores globose or elliptical, epispore rough or smooth.

Lycoperdon, Tournef., Inst. R. Herb. 563; Fries, Syst. Myc. iii, p. 27; Vitt., Mon. Lyc.; Mass., Mon. Lyc. p. 3; Sacc., Syll. vii, p. 106 (all in part).

Utraria, Quel. (in part).

Up to the present the distinctions between *Lycoperdon* and *Bovista* have been drawn chiefly from external characters, and more especially depending on the nature of the outer layer of the peridium, which more extended observations have shown to be valueless from a generic point of view. If it is necessary to keep up the two genera, the distinction must be founded on the presence or absence of a distinct sterile basal stratum, and this character, while dealing only with restricted localities, appears reasonable, but when an

examination of all the known species is undertaken, it is discovered that the numerous transitions from a well-developed sterile base, as in *L. gemmatum*, to its total absence in *B. nigrescens*, shakes one's faith as to the generic value of this character, and although both genera are kept up, it must be distinctly understood that I consider the distinctions given as artificial and not existing in nature. Pedicellate spores are common to both genera, and are not of specific value. In Saccardo's Sylloge, the generic character admits only those species with a sterile base, but this distinction is disregarded in the descriptive portion.

A. *Spores Rough.*

Lycoperdon echinatum, Pers. (Fig. 32). Peridium obovate or subglobose, at first covered with long, pyramidal, tapering purple-brown spines, between which are minute mealy warts of the same colour, mouth small, irregularly torn; root consisting of long white cord-like fibres. Mass of capillitium and spores purple-umber, threads densely interwoven, about equal to diameter of spores, much branched, continuous with the well-developed, cellular, pale ochraceous sterile basal stratum; spores purple-umber, spherical, coarsely warted, 6 μ diameter.

Lycoperdon echinatum, Pers., Symb. Myc. p. 36; Pers., Syn. 147; Mass., Mon. Lyc. n. 2.

Lycoperdon gemmatum, γ *echinatum*, Fr., Syst. Myc. iii, p. 37; Wint., Kr. Fl. 904; Sacc., Syll., vii, pp. 107 and 476.

Utraria echinata, Quel., Champ. Jur. et Vosg. ii, t. 3; Quel., Enchirid. 241.

Exs.—Fuckel, Fung. Rhen. 2486.

In woods amongst leaves, generally solitary. Dinmore! Coed Coch! Seven Oaks! Chiselhurst! Scarborough! Downton! Reading! Wrotham! Marlow! Aboyne!—Europe; United States.

From 1–1½ in. across. The spines are often curved at the apex and split in a fibrillose manner at the base; after

falling away the peridium presents a tessulated appearance as in *L. Hoylei.*

Lycoperdon Hoylei, Berk. (Fig. 68). Peridium subglobose, densely covered with stout, long, pyramidal, purple-brown, deciduous spines, which become smaller and paler in colour on the stout stem-like base; between the spines are minute, brown, persistent warts; mouth small, irregularly torn; root of long white fibres. Capillitium dense, continuous with the compact, bright-olive sterile base, thickest threads wider than diameter of spores, sparsely branched; spores bright lilac, becoming tinged with purple, globose, minutely warted, often furnished with a long hyaline pedicel, 5 μ diam.

Lycoperdon Hoylei, B. and Br., Ann. Nat. Hist. n. 1037; Mass., Mon. Lyc. n. 1; Sacc., Syll. vii, pp. 125 and 476.

On the ground amongst leaves under trees. Reading! Cheltenham!

Peridium 1–2 in. across; stem-like base ½–1 in. long, ⅔ in. thick, sometimes almost obsolete. The spines are frequently curved, and exhibit a tendency to split up in a fibrillose manner from the base. When the spines fall away the peridium presents a tessulated appearance owing to the dark persistent minute warts which surround the pale scars left by the fallen spines. Resembling *L. echinatum* in general appearance, but readily distinguished by the compact, non-cellular, bright-olive sterile basal portion, which is produced into a stem-like base, and size and colour of the spores.

Lycoperdon atropurpureum, Vitt. (Fig. 71). Subglobose or pyriform, sessile or with a short stem-like base, plicate below; peridium thin, flaccid, covered with brownish slender spines, becoming glabrous above, dehiscing by a minute irregular mouth. Capillitium continuous with the well-developed cellular sterile base; spores blackish purple, spherical, warted, sometimes pedicellate, 6–7 μ diam.

Lycoperdon atropurpureum, Vitt., Mon. Lyc. p. 186,

t. 2, f. 6: 'Science Gossip,' Dec. 1886; Cke., Hdbk. n. 1085; Mass., Mon. Lyc. n. 7; Sacc., Syll. vii, pp. 123 and 477.

Lycoperdon quercinum, Pers., Syn. 147–8.

Lycoperdon esculentum, etc., Mich., Gen. t. 97, f. 4.

Utraria atropurpurea, Quel., Enchirid. 242.

In oak woods, etc. Batheaston! Bristol! Deer Leap, Abinger, Surrey! Castle Howard, Yorks.!—Europe; U. States.

Distinguished from small forms of *L. echinatum* by the slender spines, larger spores, and dark-brown cellular base, and from *L. gemmatum* by the warted spores. Size variable, from 1–2½ in. across.

Lycoperdon excipuliforme, Scop. (Fig. 64). Peridium subglobose or depressed, passing into a stout stem, at first with slender spinose warts, which partly disappear, leaving the surface tomentose; stem rather plicate at the base. Threads of capillitium flexuous, rarely branched, continuous with the sterile cellular base; spores globose, dirty olive, minutely warted, 4–5 μ diam.

Lycoperdon excipuliforme, Vitt., Mon. Lyc. 193; Schaeff., Ic. t. 187; Bull., t. 450 and t. 475?; Paulet, p. 121, t. cci, f. 6; Karst., Myc. Fenn. p. 362; Nees, Pilze, t. 11, f. 126; Fr., Sverig. Svamp. pl. lxxiii; Pers., Syn. 143; Pabst, Crypt. Fl. t. 23; Mass., Mon. Lyc. n. 22; Sacc., Syll. vii, pp. 108 and 478.

Lycoperdon gemmatum, Berk., Eng. Fl. p. 304 (in part).

Lycoperdon gemmatum, γ *excipuliforme*, Fr., Syst. Myc. iii, p. 37; Wint., Kr. Fl. 904.

Utraria excipuliforme, Quel., Champ. Jur. et Vosg. 360; Quel., Enchirid. 241.

In woods and meadows. Carlisle!—Europe.

Variable in size, from 1–4 in. high. Often closely resembling *L. saccatum* in external appearance, but distinguished by the flexuous threads of the capillitium and the smaller and less coarsely warted spores.

Lycoperdon saccatum, Vahl (Fig. 60). Stipitate; peridium spherico-depressed, obtuse, plicate below; above with small

spinulose warts, which become smaller and fibrillose below and on the stem, dehiscing by a small irregular apical aperture; stem stout, more or less elongated, nearly equal, often more or less lacunose, pale and cellular within. Capillitium compact, persistent, threads branched, axils not rounded, thinner than diameter of spores; sterile basal portion well developed, convex, cellular; spores olivaceous-umber, strongly echinulate, spherical, about 6 μ diam.

Lycoperdon saccatum, Vahl, Fl. Dan. t. 1139; Fr., Syst. Myc. iii, 35; Berk., Outl. p. 302; Price, pl. 3, f. 14; Hussey, i, pl. 26; 'Science Gossip,' Dec. 1866, f. 251; Cke., Hdbk. n. 1087; Krombh., t. 30, f. 11–12; Mass., Mon. Lyc. n. 21; Wint., Kr. Fl. 901; Sacc., Syll. vii, pp. 128 and 477.

Utraria saccata, Quel., Champ. Jur. et Vosg. 461; Quel., Enchirid. 241.

Exs.—Cooke, Fung. Brit. n. 214.

In thickets and open woods, amongst moss. Bristol! Laxton! Kew! Highgate! Scarborough! Carlisle! Bodryddan, Flintshire! Forres, N.B.!—Europe; N. America; South Africa; S. Australia.

Peridium thin, becoming smooth, 1–2 in. across, usually plicate below, but not invariably so; stem 2–3 in. long, 1 in. thick, the whole plant sometimes much larger. Often superficially resembling *L. perlatum*, but readily distinguished by the obtuse peridium and echinulate spores. Some forms closely resemble externally *L. gemmatum*, but are distinguished by the strongly echinulate spores.

Lycoperdon gemmatum, Batsch (Fig. 30). Stipitate; peridium subglobose, depressed above, or lens-shaped, obtuse, with prominent sharp-pointed brown spinose warts of various sizes, which fall away leaving the surface smooth and shining, dehiscing by a small aperture at the apex; stem-like base stout, tapering downwards. Capillitium continuous with the prominent cellular sterile base, threads lax, rarely branching, axils acute, tapering; spores olivaceous-umber, globose, minutely verruculose, 4 μ diam.

Lycoperdon gemmatum, Batsch, Elench. p. 147; Hussey, i, pl. 54; 'Science Gossip,' Dec. 1866; Berk., Eng. Flor. 304 (including *L. perlatum*); Winter, Kr. Fl. 904; Sacc., Syll. vii, pp. 106 (in part) and 479.

Lycoperdon gemmatum, β *perlatum*, Fries, Syst. Myc. iii. 37.

Utraria gemmata, Quel., Champ. Jur. et Vosg. 358; Quel., Enchirid. 242.

Exs.—Sydow, Myc. March. nos. 1208 and 685; Rab., Fung. Eur. 1217; Thum., Fung. Austr. 724; Thum., Myc. Univ. 1611.

Amongst grass and ferns in woods and shady places. Highgate! Kew! Hereford! Scarborough! Carlisle!—Europe; N. America; Himalayas (7-8000 ft.); N. W. India; Somerset East (Africa); Swan River and Illawarra, Australia; Tasmania; New Zealand; Solomon Islands.

Distinguished from *L. perlatum* by the obtuse apex of the peridium, the long, pointed, brown, spinose warts, the sparsely branched threads of the-capillitium, and the warted spores. Peridium 1–2 in. across, stem 1½–2 in. long.

There is a form in Herb. Berk. Kew from Sikkim Himalayas with the peridium fusiform, in some of the specimens elongated, and not much thicker than the stem; but it agrees with typical forms in the capillitium and spores, and is connected by transitional stages from various countries.

B. *Spores Smooth.*

Lycoperdon pyriforme, Schaeff. (Fig. 61). Pyriform or subglobose, rather umbonate, peridium thin and flaccid, at first covered with minute pointed warts, becoming smooth, dehiscing by a small torn mouth; root of numerous white, long, branching fibres. Threads of capillitium thicker than diameter of spores, branched, continuous with the slightly cellular base, and forming a columella; spores olive, globose, smooth, about 4 μ diam.

Lycoperdon pyriforme, Schaeffer, Icon. t. 185; Price, pl. 15. 'Science Gossip,' Dec. 1866; Fries, Syst. Myc. iii, 38; Hussey, i, pl. lxx; Cke., Hdbk. n. 1089; Berk., Eng. Flor.

304; Mass., Mon. Lyc. n. 36; Karst., Myc. Fenn. iii, 362; Barla, t. 46, f. 10–11; Wint., Kr. Fl. 905; Vitt., Mon. Lyc. 196, t. 2, f. 9; Grev., t. 304; Fl. Dan. t. 1680, f. 1.

Utraria pyriformis, Quel., Champ. Jur. et Vosg. 360; Quel., Enchirid. 242.

Exs.—Sacc., Myc. Ven. 108; Cke., Fung. Brit. 517 and 215; Klotzsch (Rab.), Herb. Myc. 142: Oudem., Fung. Néerl. 119; Desm., Cr. Fr. sér. i, 526; Jack, Leiner u. Sitzenberger, Krypt. Badens, 552; Thum., Fung. Austr. 839; Fuckel, Fung. Rhen. 1260: Karst., Fung. Fenn. 286; Roumeg., Gall. 3309; Sydow, Myc. March. 917; Rav., Fung. Amer. 469; Rav., Fung. Car. 72; Fung. Cubenses Wrightiani, 501.

On rotten wood and on the ground. Generally distributed. Chiselhurst! Kew! Norwich! Chester! Scarborough! Carlisle! Edinburgh!—Europe; North America; Arctic America; Cuba; Venezuela; Galapagos Islands; Sikkim Himalayas (4–7000 ft.); Bombay; Japan; New Guinea; Tasmania; New Zealand; Australia.

Generally tufted, especially when growing on wood, and held together by numerous white fibrous cord-like strands of mycelium. The typical form of the peridium is pyriform or turbinate, with a distinct umbo, but a subglobose almost sessile peridium is not unusual.

Var. **excipuliforme**, Desmaz.

Caespitose, peridium subglobose, rufous-umber, covered above with very slender conical warts, contracted abruptly into a slender, equal, elongated stem-like base, root of long, white, cord-like strands. Capillitium and spores as in type.

Lycoperdon pyriforme, var. *excipuliforme*, Desm., Crypt. France, sér. i, no. 1152; Mass., Mon. Lyc. n. 36.

On the ground. Kew Gardens!—France.

Readily distinguished from the typical form by the subglobose peridium and elongated, equal, slender, stem-like base.

Lycoperdon perlatum, Pers. (Fig. 31). Peridium variable, subglobose with an elongated stem-like base; subglobose or

depressed and nearly sessile, often plicate below, always umbonate, ochraceous or dirty brown, at first covered with stout, obtuse, short spines, each surrounded by a ring of smaller warts which remain after the former have fallen away, becoming smaller downwards, mouth small, at apex of umbo, stem-like base pale, slightly cellular and convex above. Capillitium forming a loose columella, threads rarely branched, flexuous, about equal in thickness to diameter of the globose, smooth, olivaceous spores, 4 μ diam.

Lycoperdon perlatum, Pers., Syn. p. 145; Barla, pl. 46, f. 8; Vitt., Mon. Lyc. 194; Mass., Mon. Lyc. n. 31; Sacc., Syll. vii, pp. 107 and 479.

Lycoperdon gemmatum, Fr., Syst. Myc. iii, 35; Fries, Sverig. Svamp. t. lxxiii; Fl. Dan. MCXL; Krombh., t. 30, f. 6; Cke., Hdbk. n. 1088 (including *Lyc. gemmatum*); Palist., Crypt. Fl. t. 23; Karst., Myc. Fenn. 361.

Lycoperdon constellatum, Sturm, t. 7?

Lycoperdon gemmatum, var. *perlatum*, Wint., Kr. Fl. 904.

Lycoperdon lacunosum, Bull., t. 52?

Lycoperdon hirtum, Bull., t. 340?

Exs.—Karst., Fung. Fenn. 920; Moug. and Nest., St. Cr. 577.

In woods and thickets. Kew! Audley End, Essex! Dinmore! Scarborough! Carlisle!—Europe; United States; Gippsland, Australia; E. Nepal.

Closely allied to *L. gemmatum*, but distinguished by the well-marked umbo, distinct columella, paler colour, and smooth spores. The peridium is often plicate below and the stem more or less lacunose. Often springing in pairs from the same base, sometimes in clusters of from four to seven; not uncommon, solitary. Peridium 1–2 in. across, stem 2–3 in. high, 1–1½ in. thick. Sometimes larger.

Lycoperdon molle, Pers. (Fig. 65). Turbinate, base broad, abrupt, peridium papyraceous, collapsing, furfuraceous, becoming smooth, dehiscing by a small irregular mouth. Threads of capillitium thicker than diameter of spores, collapsing;

sterile base well developed, slightly cellular, marginate, becoming almost free from the capillitium; spores ochraceous-olive, globose, smooth, 4 μ diam.

Lycoperdon molle, Pers, Syn. 150.

Lycoperdon gemmatum, Berk., Eng. Flor. (in part).

Lycoperdon molle, Sacc., Syll. vii, p. 107.

Size of *L. pyriforme*, colour much darker, almost dilute olive, very soft to the touch, root none (Pers.).

On the ground in oak woods. King's Cliffe!—Europe; United States.

Lycoperdon caelatum, Bull. (Fig. 58). Subglobose or depressed, contracted below into a more or less elongated stem-like base, often furnished with a long tapering root; peridium at first covered with rather large, distant, conical warts, disappearing above and leaving the peridium almost smooth, more persistent below, and becoming split from the base; upper portion of peridium evanescent; capillitium ochraceous olive, with a tinge of lilac, threads frequently branched, axils rounded, thicker than diameter of spores; sterile base cellular, slightly convex, dense, at length free from the capillitium; spores dirty olive, spherical, smooth, 5 μ diam., frequently furnished with a hyaline pedicel, 2–3 times as long as diameter of spore.

Lycoperdon caelatum, Bull., Champ. t. 430; Fr., Syst. Myc. iii, 32; Vitt., Mon. Lyc. 188; Berk., Outl. t. 20, f. 7; Berk., Eng. Flor. 303; Krombh., t. 30, f. 7–10; Harzer, t. lxxiv; Schaeff., t. cxc; Nees, Pilze, t. 10, f. 1; Hussey, ii, pl. 23; Cke., Hdbk. 1084; Barla, pl. 46, f. 4; Wint., Kr. Fl. 897; Mass., Mon. Lyc. n. 47; Sacc., Syll. vii, p. 115.

Lycoperdon gemmatum, Schaeff., Ic. t. 189, f. 1–3.

Lycoperdon bovista, Nees, Pilze, t. 11, f. 125.

Bovista officinarum, Sturm, t. 1.

Utraria caelata, Quel., Champ. Jur. et Vosg. 360; Quel., Enchirid. 241.

Generally distributed, but not common. Fields, woods, roadsides, etc. Batheaston! Sydenham! Kew! Scarborough! Carlisle! Aboyne! Aviemore, N. B.!—Europe; N. America;

Behrings Straits; Falkland Islands; Cuba; Neelgheries; Darzeeling; Tasmania; New Zealand; Australia; Algeria.

Very variable in form, peridium globose, or more frequently spherico-depressed, 1–4 in. across, stem-like base stout, variable in length, and often attenuated downwards, sometimes almost obsolete.

Lycoperdon bovista, Linn. (Fig. 76). Peridium globose or depressed, often more or less plicate at the base, sessile; cortex thick, at first subtomentose, becoming smooth, fragile, and evanescent above, leaving a wide opening. Capillitium compact, continuous with the sterile cellular base; spores bright yellow, becoming dusky olive, globose, smooth, rather variable in size, 4–6 μ diam., sometimes pedicellate.

Lycoperdon bovista, Linn., Sp. Pl. 1653; Vitt., Mon. Lyc. 181; Fr., Syst. Myc. iii, 29; Karst., Myc. Fenn. iii, 360; Fr., Sverig. Svamp. lxxii; Bull., 447; Wint., Kr. Fl. 899; Mass., Lyc. n. 45; Sacc., Syll. vii, p. 109.

Lycoperdon giganteum, Fl. Dan. MDCCCXX; Hussey, i, pl. 26; Pabst, Crypt. Flor. t. 23; Cke., Hdbk. n. 1083; Berk., Eng. Flor. 303; Batsch, Elench. 238, t. 39, f. 165; Sow., t. 332, upper fig.; Corda, Ic. Fung. v, f. 40.

Lycoperdon maximum, Schaeff., Ic. 191.

Bovista gigantea, Nees, Pilze, t. xi, f. 124, *C*; Grev., Scot. Cr. Fl. t. 336.

Langermannia gigantea, Sturm, t. 10.

Globularia gigantea, Quel., Champ. Jur. et Vosg. 362; Quel., Enchirid. 239.

Exs.—Flora Exs. Aust.-Hung. 1156; Karst., Fung. Fenn. 374.

Grassy places. Summer and autumn. East Bergholt! Peckham! Castle Howard, Yorks.! Scarborough! Carlisle! —Europe; N. America.

Grows to a large size, sometimes a foot or more in diameter.

Lycoperdon Cookei, Mass. (Fig. 26). Hemispherical and flattened below or globose, abruptly contracted into a short,

thick, stem-like base, smoky brown above, becoming whitish below, minutely areolato-furfuraceous, dehiscing by a small irregular aperture. Capillitium continuous with the well-developed whitish cellular sterile base, threads variable in thickness, simple, firm; spores bright citrin, then olivaceous-umber, globose, smooth, sometimes pedicellate, 4 μ diam.

Lycoperdon Cookei, Mass., in Herb. Kew; Mass., Mon. Lycoperd. n. 52, Pl. xiii, Figs. 24–26 (Type in Herb. Kew); Sacc., Syll. vii, p. 481.

Lycoperdon pusillum, Cooke, in 'Science Gossip,' with fig., Dec. 1866.

On the ground. Kew Gardens! Norfolk!—Port Jackson, Australia; Albany, U. States.

This species has hitherto been confounded with *B. pusillum*, from which it is readily distinguished by the presence of a well-developed, convex, sterile base, and absence of the long, slender, tapering root characteristic of *B. pusillum*. Gregarious. From $\frac{1}{2}$–$\frac{3}{4}$ in. across.

GEASTÉR, Micheli.

Peridium at first continuous, consisting of three layers, the two outermost (exoperidium) usually continuous, splitting from the apex in a stellate manner; inner layer (endoperidium) sessile or pedicellate, furnished at the apex with one, rarely more orifices; columella prominent or rudimentary; capillitium dense; spores coloured.

Geaster, Mich., Nova Plant. Gen. p. 220; Fries, Syst. Myc. iii, p. 9; Berk., Outl. p. 229; Sacc., Syll. vii, p. 70.

Actinodermium, Nees.

Myriostoma, Desv. (in part). *Plecostoma*, Desv. *Sterrebeckia*, Link. (in part). *Lycoperdon*, of various old authors.

'In one species (*G. coliformis*) the inner peridium (endoperidium) is supported by several stems, and the orifices are numerous. This has led to its removal by some mycologists from this to a new genus. We prefer to retain it as a subgenus. In the rest the orifice and support is single.' (M. C. C.)

Sub-Gen. **Myriostoma.** Orifices and peduncles indefinite in number.

Geaster coliformis, Pers. (Fig. 66). Exoperidium multifid, segments unequal, acute, inflexed, reflexed, or expanded; endoperidium spherical or depressed, supported on numerous slender pedicels which are often more or less compressed and branched; orifices numerous, ciliated; spores in the mass umber, globose, warted, 5–6·5 μ, threads of capillitium simple, equal, often flexuous, 5–6 μ diam.

Geaster coliformis, Pers., Syn. p. 131; Berk., Engl. Fl. v, p. 299; Berk., Outl. p. 210; Cooke, Hdbk. n. 1070; Fries, Syst. Myc. iii, p. 12; Grev., ii, t. 15, f. 1; Winter, Kr. Fl. p. 909; De Toni, Revis. Geast. n. 1, pl. 1, f. A; Sacc., Syll. vii, p. 73.

Lycoperdon coliforme, Dickson, Plant. Crypt. Brit. i, p. 2, t. 3, f. 4; Sow., Eng. Fungi, t. 313.

Myriostoma coliformis, Corda, Anleit. t. D, f. 16–17.

Exs.—Fuckel, Fung. Rhen. n. 2291.

In sandy places. Norfolk!—Europe.

Readily distinguished by the numerous peduncles and orifices. Exoperidium from three to four inches across when expanded. The threads of the capillitium are equal with short tapering ends, and in some instances have a rudimentary branch near the tip.

Sub-Gen. **Eu-Geaster.** Orifice and pedicel single, or the latter absent and the endoperidium sessile.

A. *Endoperidium pedicellate.*

Geaster Bryantii, Berk. (Fig. 56). Exoperidium coriaceous, cut into from 8–10 irregular acute segments, which are at first expanded, then involute; endoperidium subglobose, pedicellate, with a distinct permanent groove round the apex of the peduncle; peristome conical, sulcato-striate; spores in the mass dark brown, globose, warted, 4–6 μ; threads of capillitium subfusiform, variable in thickness, rarely with rudimentary lateral branches near the tips.

Geaster Bryantii, Berk., Engl. Flora, v, p. 300; Berk., Outl. p. 300; Cooke, Hdbk. n. 1073; Wint., Kr. Fl. p. 911; Quel., Enchirid. p. 237; De Toni, Revis. Geast. n. 8, pl. 1, f. D; Sacc., Syll. vii, p. 75.

Geaster orientalis, Haszl. Grev. vi, p. 108, t. 98, f. 15.

Lycoperdon, Bryant, Hist. f. 19; Schmid., Icon. t. 37, figs. 11, 12.

Exs.—Berk., Brit. Fung. n. 198.

On the ground amongst leaves, etc. Apethorpe, Northts.! Ely! Chiselhurst! Thorney, Camb.! (Type in Herb. Berk. Kew, n. 4552.)—Germany; France; United States; Ceylon.

Distinguished by the groove round the top of the peduncle and the elongated conical, plicate peristome. From 1½–2 in. across when expanded.

Var. **minor**, Berk.

Smaller than the typical form, when expanded from ¾ to 1 in. across.

Geaster Schmideli, Vitt. (Fig. 74). Exoperidium split to the centre into 5–8 subequal acute segments, whitish inside; endoperidium globoso-ovate, lead-colour, pedicellate; peristome prominent, plicate, apex fimbriate, spores in the mass blackish-umber, globose, warted, 4–6 μ; columella thick, half as high as the endoperidium, threads of capillitium simple, fusiform, 6–7 μ at thickest part.

Geaster Schmideli, Vitt., Mon. Lyc. p. 157, t. 1, f. 7; Winter, Kr. Fl. p. 911; De Toni, Rev. Geast. n. 11, pl. i, M; Sacc., Syll. vii, p. 76.

Geaster Rabenhorstii, Kunze, in Rab., Fung. Eur. n. 2011.

Exs.—Rab., Fung. Eur. n. 2011; Kunze, Fung. Sel. 10; Syd., Myc. March. 7.

On the ground. Ascot!—Europe.

Distinguished by the whitish inner surface of the exoperidium, and the lead-coloured endoperidium from all British species.

Geaster Berkeleyi, Mass., n. sp. (Fig. 41). Exoperidium rather thin, split to the centre into 7–9 unequal acute segments, at first expanded, then slightly involute, inner stratum continuous; endoperidium supported on a short thick peduncle, broadly ovate, pale brown, coarsely papillose, peristome prominent, conical, sulcato-striate, surrounded by a smooth depressed silky zone; columella short, hemispherical; spores in the mass brownish-umber, globose, warted, 4–6 μ, threads of capillitium simple, fusiform, 10 μ at thickest part.

On the ground. Ascot! Lambley, Notts.! Laxton!—S. Australia. (Type in Herb. Berk. Kew, n. 4550.)

Allied to *G. striatus*, from which it differs in the depressed zone surrounding the peristome, its larger size, and the coarsely papillose endoperidium. Exoperidium when expanded 3–3½ in. across, endoperidium 1 in. high.

Geaster limbatus, Fr. (Fig. 69). Exoperidium multifid, segments unequal, acute, endoperidium subpyriform, seated on a short, thick pedicel, peristome depressed, conical, subacute, fimbriato-ciliate, surrounded by a pale silky circle; spores in the mass purple-brown, globose, warted, 3–5 μ; columella almost obsolete; threads of capillitium fusiform, 8–10 μ thick at the centre.

Geaster limbatus, Fries, Syst. Myc. iii, p. 15; Berk., Outl. p. 300; Berk., Eng. Fl. p. 301; Cke., Hdbk. n. 1074; Morgan, Amer. Geast. p. 996, f. 6; Wint., Kr. Fl. 913; De Toni, Rev. Geast. n. 24, pl. ii, A; Hussey, i, t. 2; Sacc., Syll. vii, p. 81.

Geastrum coronatum, Pers., Syn. p. 132.

Geastrum multifidum, D. C., Fl. Fr. ii, p. 267.

Lycoperdon, Sow., t. 312.

Exs.—Rab., Fung. Eur. 674; Fuckel, Fung. Rhen. 1599?; Syd., Myc. March. 103; Ellis, N. Amer. Fung. 1309.

On the ground. Reading! Lambley, Notts.! Maidenhead! Kent! Castle Howard, Yorks.!—United States; Canada; Somerset East (Africa); S. W. Australia; Thibet.

Differs from *G. rufescens* in the presence of a pedicel.

'The inner peridium (endoperidium) is slightly constricted, and then swollen at the base, without any groove round the top of the peduncle, into which it passes gradually.' (Berk. in Engl. Flora.)

Geaster fornicatus, Fr. (Fig. 42). Exoperidium split into 4–5 subequal acute segments, the two layers separating, exterior cup-shaped, remaining attached to the ground, the inner becoming arched and attached to the outer by the tips of the segments; endoperidium shortly pedicellate, obpyriform, peristome conical, ciliato-sulcate; spores in the mass dark brown with tinge of purple, globose, warted, 3–5 μ; columella slender, clavate, threads of capillitium fusiform, 5–7 μ at thickest part.

Geaster fornicatus, Fries, Syst. Myc. iii, p. 12; Berk., Eng. Fl. p. 300; Berk., Outl. p. 299; Cke., Hdbk. n. 1071; Wint., Kr. Fl. p. 912; Quel., Enchirid. p. 237; De Toni, Rev. Geast. n. 3, pl. i, B; Sacc., Syll. vii, p. 73; Morgan, Amer. Geast. p. 964, f. 1.

Lycoperdon fornicatus, Huds, Fl. Angl. p. 644; Sow., Engl. Fung. t. 198.

Lycoperdon coronatum, Schaeff., Ic. t. 183.

Lycoperdon fenestratum, Batsch, Elench. f. 168.

Geastrum quadrifidum, D. C., Fl. Fr. ii, p. 267; Nees, Pilze, t. 12, f. 128.

Plecostoma fornicatum, Cda., Anleit. t. D, f. 12–15.

Exs.—Rab., Fung. Eur. nos. 430, 2013, and 2013 *b*; Zopff and Syd., Myc. March. 53; Klotzsch, Herb. Myc. 140; Fuckel, Fung. Rhen. 1267; Thum., Fung. Austr. 335; Thum., Fung. Univ. 526; Schultz, Herb. normale, nov. ser. Cent. 4, n. 397; Kunze, Fung. Sel. 11.

On the ground. Lucknam, Wilts! Stapleton! Castle Howard, Yorks.! Chiselhurst! Luton, Beds.! Worcester! —Europe; United States.

Very variable in size, but readily distinguished amongst British species by the complete separation except at the tips of the two layers forming the exoperidium, and the inner layer becoming arched. *Geaster radicans*, Berk. and Curt., a North

American species, has a similar habit, but differs in the silky peristome not being sulcate.

B. *Endoperidium sessile.*

Geaster mammosus, Chev. (Fig. 78). Exoperidium hygrometric, split nearly to the base into 7–10 acute segments; endoperidium sessile, pale; peristome conical, acute, fimbriato-ciliate, surrounded by a pale, narrow, silky circle; spores in the mass dark brown with a tinge of purple, globose, warted, 4–6 μ; columella short, threads of capillitium fusiform, simple, 6–7 μ at thickest part.

Geaster mammosus, Chev., Fl. Paris, p. 359; Fries, Syst. Myc. iii, p. 17?; Vitt., Mon. Lyc. p. 155, t. 1, f. 9; Berk., Eng. Flora, p. 301; Berk., Outl. p. 300; Cke., Hdbk. n. 1076; De Toni, Revist. Geast. n. 33, pl. ii, G?; Sacc., Syll. vii, p. 85?; Wint., Kr. Fl. p. 914; Quel., Enchirid. p. 238.

Lycoperdon recolligens, Sow., t. 401.

On the ground, specimen from Sowerby's collection, now in Herb. Berk. Kew!—Europe.

Exoperidium from 1–2 inches across when expanded. It is doubtful whether Fries had the right plant in view, as he states that the exoperidium is revolute when dry, whereas in Sowerby's specimen and figure quoted above the exoperidium is strongly involute when dry, as is also shown in Vittadini's figure. De Toni's description in Rev. Geast., repeated in Sacc., Syll., is still more doubtful, as the spores are stated to be from 2–3·5 μ in diameter. The North American specimens under this name are certainly not the true species. The present plant bears some external resemblance to *G. hygrometricus*, but is readily distinguished by the columella and conico-acute peristome surrounded by a pale circle.

Geaster fimbriatus, Fr. (Fig. 77). Exoperidium flaccid, split into 5–15 subequal, acute segments, inner layer soon disappearing; endoperidium subglobose, sessile, mouth indeterminate, piloso-fimbriate; spores in the mass blackish umber, globose, minutely verruculose, 3–4 μ; threads of capillitium simple, fusiform, 6–7 μ at thickest part.

Geaster fimbriatus, Fries, Syst. Myc. iii, p. 16; Berk., Outl. p. 300, pl. 20, f. 4 (mouth of endoperidium not correct); Cke., Hdbk. n. 1075; Grev., ii, pl. 17, f. 2; Wint., Kr. Fl. p. 313; Quel., Enchirid. p. 239; De Toni, Rev. Geast. n. 28 (excl. *Geaster australis*, Berk.); Sacc., Syll. vii, p. 82; Morgan, Americ. Geast. p. 967, f. 8.

Lycoperdon geaster, Batsch, Elench. p. 151.

Exs.—Rab., Fung. Eur. 431 and 165; Zopff and Sydow, Myc. March. 8; Cke., Fung. Brit. 213; Roumeg., Fung. Sel. Gal. 510; Fuckel, Fung. Rhen. 1266; Thum., Myc. Univ. 411; Kunze, Fung. Sel. 8.

On the ground. Audley End, Essex! Bristol! Milton, Somerset! Castle Howard, Yorks.! Cork!—Europe; North America; Cuba; Himalayas; Tasmania; New Zealand; S. Australia; Brazil.

Agreeing with *G. hygrometricus*, in the indefinite mouth of the endoperidium, but distinguished by the segments of the exoperidium not becoming incurved when dry, and the almost smooth spores. The latter character and the non-dentate mouth separates it from *G. rufescens*.

Geaster rufescens, Pers. (Fig. 79). Exoperidium rigid, thick, split nearly to the base into a variable number of acute segments which become revolute; endoperidium sessile, sub-ovate, pale, peristome dentate; spores in the mass blackish-brown, globose, verruculose, 3–5 μ; columella short, sub-globose; threads of capillitium simple, fusiform, 8–13 μ thick at widest part.

Geaster rufescens, Pers., Syn. Fung. p. 134; Fries, Syst. Myc. iii, p. 18; Berk., Outl. p. 300; Cke., Hdbk. n. 1077; De Toni, Rev. Geast. n. 41, pl. ii, f. 9; Sacc., Syll. vii, p. 88; Grev., ii, pl. 19, f. 2; W. G. Smith, in Gard. Chron., Oct. 1875, Fig. 116; Fl. Dan. t. 1433; Quel., Enchirid. p. 238 (in part); Wint., Kr. Fl. p. 914.

Lycoperdon stellatum, Bull., Champ. t. 471, f. 1.

In pastures and woods. Wrekin Woods, Salop! Chiselhurst, Kent! Ascot! Leicester! King's Cliffe!—Europe; Balearic Isles; United States; S. California; Cuba; S. Australia; New South Wales.

Variable in size, from 2–4 inches across when expanded; number of segments varying from 6–10. Distinguished from *G fimbriatus*, which it somewhat resembles by the distinctly dentate peristome.

Geaster hygrometricus, Pers. (Fig. 70). Exoperidium split into a varying number of subequal acute lobes, which are rigidly inflexed when dry; inner stratum thick, often cracked; endoperidium sessile, usually depressed, subreticulate, rarely smooth, dehiscing by an apical irregularly torn aperture; spores in the mass dark-brown, globose, warted, 7–10 μ; columella obsolete; threads of capillitium branched, subequal, 5–6 μ thick.

Geaster fornicatus, Pers., Syn. Fung. p. 135; Fries, Syst. Myc. iii, p. 19; Berk., Eng. Flora, p. 302; Berk., Outl. p. 301; Cooke, Hdbk. n. 1078; De Toni, Rev. Geast. n. 47; Sacc., Syll. vii, p. 90; Winter, Kr. Fl. p. 914; Quel., Enchirid. p. 239; Vitt., Mon. Lyc. p. 108, t. 1, f. 8; Morgan, Amer. Geast. p. 969, f. 12.

Lycoperdon stellatum, Bull., Champ. t. 138, f. *a–d*; Bolton, t. 179.

Exs.—Crypt. Lusit. 18; Rav., F. Amer. 471; Ellis, N. Amer. Fung. 108; Rav., F. Car. 75; Fuckel, Fung. Rhen. 1263; Mong. and Nest., 1195; Jack, Leiner u. Stz. 624; Roumeg., Fung. Sel. Gall. 509; Desm., Cr. Fr. sér. 1, 955; Rab., Fung. Eur. 2009; Syd., Myc. March. 1114; Cooke, Britt. Fung. 514; Thum., Myc. Eur. 110; E. Bourgeau, Plantae Canar. 1216; Erb., Critt. Ital. i, n. 1145; Linhart, Fung. Hung. 151.

On the ground. Shrewsbury! Bovey Tracey! Hereford! Scarborough!—Europe; W. Africa; Teneriffe; United States; Mexico; Uraguay; Madagascar; N.-W. India; Afghanistan; Japan; S.-W. Australia.

Exoperidium 2–3½ in. across when split and expanded, hygroscopic, readily distinguished by the segments of the endoperidium, which vary in number from 7–20, being rigidly incurved when dry, and the scurfy or reticulate endoperidium bursting irregularly.

Geaster lageniformis, Vitt. (Fig. 75). Exoperidium ovate-acuminate, splitting into 7–9 subequal acute segments, inner stratum soft, disappearing; endoperidium subglobose, sessile, peristome plano-conic, silky, striate, surrounded by an orbicular silky zone; spores in the mass umber with olive tinge, minutely verruculose, globose, 3–4 μ; columella clavate, threads of capillitium fusiform, simple or slightly branched towards the tips, 7–9 μ thick at the widest part.

Geaster lageniformis, Vitt., Mon. Lyc. p. 160, t. 1, f. 2; Grev., ii, t. 14, f. 1; De Toni, Rev. Geast. n. 36, pl. ii, B; Sacc., Syll. vii, p. 86; Morgan, Amer. Geast. p. 958, f. 10.

On the ground. Stoke Wood, Exeter!—Europe; United States; South-West Australia.

Four examples of this species sent by Vittadini to the Rev. M. J. Berkeley are now in the Berkeley collection of fungi in the Kew Herbarium. Liable to be confounded with *G. Michelianus*, from which the present species differs in the sessile endoperidium, and the presence of a silky zone surrounding the peristome.

Geaster Michelianus, W. G. Smith (Fig. 27). Exoperidium thick, often much cracked externally, splitting to the middle into 4–6 subequal acute segments, inner stratum thick, becoming dry and crumbling away; endoperidium subsessile, peristome plano-conic, ciliato-fimbriate, pale; columella large, clavate; spores in the mass brownish umber, globose, warted, 4–5 μ; threads of capillitium fusiform, 6–8 μ at widest part.

Geaster Michelianus, W. G. Smith, Gard. Chron. 1873, n. 18; De Toni, Rev. Geast. n. 31, pl. ii, f. N; Sacc., Syll. vii, p. 84.

Geaster tunicatus Michelianus, in Erb., Critt. Ital. ser. 1, n. 879.

Geaster lageniformis, Cke., Hdbk. n. 1079, Fig. 113; Grev., ii, p. 35, pl. 13.

Exs.—Erb., Critt. Ital. ser. 1, n. 879, and ser. 2, n. 343.

On the ground. Castle Ashby, Norths.! Hawkhurst, Kent! Holyhead!—Italy; Germany.

A fine species, recognised by the very thick rigid exoperidium

and the elongated clavate columella. The young plant is ovate-acuminate before the rupture of the exoperidium; the latter when spreading measures 2–3 inches across.

Geaster striatus, D. C. (Fig. 28). Exoperidium split into 6–9 subequal coriaceous, thin, acute segments; endoperidium subsessile, globose, often scabrid; peristome prominent, conical, sulcato-striate; spores in the mass dark umber-brown, globose, verruculose, 4–5·5 μ; threads of capillitium simple, fusiform, 7–9 μ at the thickest part.

Geaster striatus, D. C., Fl. Fr. ii, p. 267; Fries, Syst. Myc. iii, p. 13; Berk., Engl. Fl. p. 300; Berk., Outl. p. 300; Cooke, Hdbk. n. 1072; De Toni, Rev. Geast. n. 13, pl. 1, G. (excl. *Geaster Archeri*, Berk.); Sacc., Syll. vii, p. 77; Morgan, Amer. Geast. p. 965, f. 3; Winter, Kr. Fl. 909; Quel., Enchirid. p. 238.

Exs.—Rab., Fung. Eur. 2012; Kunze, Fung. Sel. 9; Thum., Myc. Univ. 527; Oudem., Fung. Néerl. 2; Fuckel, Fung. Rhen. 1264.

On the ground. Chiselhurst! Bungay! Yarmouth! Hereford!—Europe; Algeria; United States; Madras; Afghanistan; S. Australia.

Endoperidium measuring when expanded from 1½–2½ inches. Distinguished from *G. Bryantii* by the much shorter pedicel which is not furnished with a groove at the apex, and from *G. limbatus*, by the absence of a pale silky zone surrounding the peristome.

TULOSTOMA, Pers. (emended).

Peridium subglobose, dehiscing by an apical aperture, outer coat (cortex) deciduous; distinct from the elongated stem; capillitium present, threads septate, swollen at the septa.

Tulostoma, Pers., Disp. p. 6; Fries, Syst. Orb. Veg. i, p. 139.

Tylostoma, Sacc., Syll. vii, p. 60.

Tulasnodea, Fr.

Resembling a *Lycoperdon* with an elongated stem, but readily distinguished by the groove between the apex of the stem and the peridium, and the threads of the capillitium being nodulose at the transverse septa.

Tulostoma mammosum, Fr. (Fig. 33). Stem equal, more or less squamoso-fibrillose; peridium subglobose, mouth prominent, mammaeform, entire; mass of spores dirty cinnamon, threads of capillitium colourless, branched, septate; spores globose, minutely and sparsely verruculose, 5 μ diam.

Tulostoma mammosum, Fr., Syst. Myc. iii, p. 42; Berk., Outl. p. 299; Berk., Eng. Flora, v, p. 305; Cooke, Hdbk. n. 1069, f. 112; Quel., Enchirid. 236; Wint., Kr. Fl. 892; Sacc., Syll. vii, p. 60.

Tulostoma brumale, D. C., Fr. ii, p. 269; Nees, Syst. f. 130; Fl. Dan. t. 1740, f. 1; Quel., Enchirid. 236.

Lycoperdon mammosum, Mich., Gen. p. 217.

Lycoperdon pedunculatum, Linn., Suec. n. 1276; Bull., Champ. p. 161, t. 294, 471, fig. 2; Sow., t. 406.

Exs.—Cke., Fung. Brit. 402; Cke., Fung. Brit. ed. 2, 515; Roum., Fung. Sel. Gal. 209; Klotzsch, Herb. Myc. (Rab.), 30; Zopff et Sydow, Myc. March. 55; Sacc., Myc. Ven. 424; Kunze, Fung. Sel. 205; Fuckel, Fung. Rhen. 1268; Desm., Cr. Fr. sér. 1, 567; Thum., Myc. Univ. 606; Jack, Leiner u. Sitzenb. 331; Mong. and Nest., 387.

On old walls and dry banks. Charlton! Tenby! Norwich! Castle Howard, Yorks.! near Liverpool!—Europe; United States; Mexico; S. Africa.

Varying from 1–3 in. high, peridium from ½–¾ in. across; whole plant dirty brownish ochre. The stem is sometimes almost smooth, at others broken up into small irregular fibrillose squamules, which are sometimes arranged more or less in circles.

BATTARREA, Pers.

Volva universal, central stratum gelatinous. Peridium vertically compressed, bursting through the volva, and raised above ground on a tall stem.

Battarrea, Pers., Syn. Fung. p. 129; Fries, Syst. Myc. iii, p. 7; Sacc., Syll. vii, p. 65.

Lycoperdon, Sow.; Smith.

Dendromyces, Libosch.

The compressed peridium affords a ready means of distinguishing between this genus and *Tulostoma*, its nearest relation.

Battarrea phalloides, Pers. (Fig. 29). Stem cylindrical, hollow, externally broken up into coarse fibres; mass of spores yellowish brown, becoming subferruginous, capillitium of colourless branched, thin-walled, collapsing threads, mixed with a few threads with the wall thickened in a spiral manner; spores globose, minutely verruculose, 6 μ diameter.

Batarrea phalloides, Pers., Syn. Fung. p. 129, t. 3, f. 1; Fries, Syst. Myc. iii, p. 7; Berk., Eng. Flor. v, p. 298; Berk., Outl. p. 299; Cke., Hdbk. n. 1068, f. 111; Hook., Journ. Bot. (1843), t. 22, f. 1 (threads and spores); Quel., Enchirid. 236; Sacc., Syll. vii, p. 66.

Lycoperdon phalloides, Dicks., Crypt. Bot. i, p. 24; Woodw., Phil. Trans. lxxiv, p. 423, t. 26; Smith, Spic. Bot. i, p. 11, t. 12; Sow., t. 390.

On sandhills or in hollow trees at the base. Norfolk! Dropmore! New Brighton! Surrey! Specimen from Herb. Sow., now in the Herb. Berk., Kew!—France; S. Africa; Calabria.

The whole plant is at first enclosed in a volva as in *Phallus*, which is buried several inches deep in loose sand, and after the almost complete differentiation of the gleba, the peridium is elevated into the air by the sudden increase in length of the stem, which sometimes measures fourteen inches in length. When the plant is carelessly drawn up by the stem, the volva is left behind.

PHALLOIDEAE.

Receptacle and gleba at first enclosed in a universal volva having a middle gelatinous stratum; spores minute, elliptic-oblong, smooth, when mature involved in mucus.

Phalloideae, Fr., Syst. Myc. ii, p. 281; Sacc., Syll. vii, p. 1.

ITHYPHALLUS (Mich.), Fischer.

Receptacle stem-like, hollow, perforate at the apex; pileus reticulated, attached to the perforate apex of the receptaculum, otherwise free; veil absent.

Ithyphallus, Fischer, Ueber die Phalloideen, p. 41; Sacc., Syll. vii, p. 8.

Phallus, Mich., Gen. p. 201.

Phallus (*Ithyphallus*), Fries, S. M. ii, 283.

Ithyphallus impudicus, (L.) Fischer (Fig. 44). Receptacle subfusiform, perforated at the apex, hollow, colourless; pileus reticulated, attached to the perforate apex of the receptacle, otherwise free; spores immersed in olive gluten, cylindrical with rounded ends, 3–5 × 2 μ.

Phallus impudicus, Linn., Suec. n. 1261; Fl. Dan. t. 175; Schaeff., Fung. t. 196–198; Bull., Champ. t. 276, t. 182; Bolt., t. 92; Grev., Scot. Cr. Fl. t. 213; Berk., Eng. Flora, v, p. 226; Berk., Outl. 297, t. 20, f. 3; Cke., Hdbk. p. 364, f. 108; Fries, Syst. Myc. ii, p. 283; Price, Ill. Fung. pl. 20, f. 130; Quel., Enchirid. 234; Wint., Kr. Fl. 869.

Ithyphallus impudicus (L.), Fischer, Ueber die Phalloideen; Sacc., Syll. vii, p. 8.

Phallus foetidus, Sow., t. 239.

Phallus iosmos, Berk., Eng. Flor. v, p. 227 (specimen in Hb. Berk.); Phil. and Plow., Grev. iv, p. 119.

Exs.—Desm., Cr. Fr. sér. 1, 2025; Roum., Fung. Gall. Exs. 2615; Sacc., Myc. Ven. 837; Fuckel, Fung. Rhen. 1270.

In woods and bushy places, not uncommon, and readily detected at a distance of several yards by its abominable smell. Bournemouth! Kew! Chepstow! Bristol! Leeds! Scarborough! Carlisle! — Europe; United States; India (Churra).

Several sporophores of various sizes usually spring from the widely spreading white, cord-like, strands of mycelium. The plant frequently attains the size of a hen's egg before the volva is ruptured. The foetid odour is given out when the spores are mature, and attracts great numbers of large flies, who greedily devour the dripping mucus containing the spores, and thus probably assist in their dissemination.

MUTINUS (Huds.), Fr.

Receptacle stem-like, hollow, wall with a single row of

cavities, apex perforate or imperforate, pileus adnate to the receptacle; veil absent.

Mutinus, Fries, Summ. Veg. Sc. ii, 1849; Sacc., Syll. vii, p. 12.

Phallus (*Cynophallus*), Fr., Syst. Myc. ii, p. 284.

Cynophallus, Berk., Outl. p. 298.

Phallus (of old authors).

Resembling *Ithyphallus* in general appearance, but readily distinguished by the absence of a free pileus.

Mutinus caninus (Huds.), Fr. (Fig. 43). Receptacle subfusiform, apex perforate or imperforate, white or rosy, sporiferous portion short, acutely digitaliform, red; spores cylindrical, with rounded ends, 3–5 × 2 μ.

Mutinus caninus (Huds.), Fries, Summ. Veg. Sc. pt. ii; Fischer, Ueber die Phalloideen, p. 55; Sacc., Syll. vii, p. 12; Grev., vol. 17, pl. 173, figs. *a–e*

Phallus caninus, Huds., Fl. Angl. ii, p. 630. (Not Fries.)

Phallus inodorus, Sow., t. 330. (Not Fries.)

Phallus (*Cynophallus*) *caninus*, Fries, Syst. Myc. ii, p. 284; Berk., Eng. Fl. p. 227; Berk., Outl. p. 298; Cke., Hdbk. p. 365, fig. 109; Schaeff. t. 330; Fl. Dan. 1259; Price, Ill. Fung. t. 1, f. 4; Wint., Kr. Fl. 869; Quel., Enchirid. 235.

Exs.—Fuckel, Fung. Rhen. 1269.

In woods and bushy places, rather local. Sevenoaks! Lea! Kew! Scarborough! Hereford! Carlisle! Bristol! Edinburgh!—Europe; United States; Venezuela; Australia; Perak.

Mycelium cord-like, white, sporophore about the size of a hazel-nut before the rupture of the volva. Stem 3–4 in. high, ½ in. thick, pileus tuberculose, reddish, covered at first with green mucus. Scentless, or nearly so.

[**Mutinus bambusinus** (Zoll.), Fisch. Receptacle 10–12 cm. high, 1 cm. thick, bright red or pinkish, the upper half sporiferous, purplish red, acute; spores 4 × 1·5 μ, involved in very foetid olive mucus.

Mutinus bambusinus, Fischer, in Ann. du Jardin bot. de Buitzenzorg, vi, p. 30, t. iv and v, f. 26–31 (1886); Grev. vol. 17, p. 17, pl. 173, Figs. *f–l*; Sacc., Syll. vii, p. 12.

Phallus (*Cynophallus*) *bambusinus*, Zollinger, Systematisches Verzeichniss der im indischen Archipel in den Jahren 1842–48 gesammelten, sowie der aus Japan empfangenen Pflanzen, 1 Heft, Zürich, 1854, p. 11.

An East Indian species recently detected by Sir Joseph Hooker in Noble's Nursery at Sunningdale.]

CLATHRUS, Mich.

Volva becoming torn in a laciniate manner at the apex; receptacle sessile, forming an obovate or globose, hollow network, at first covered with mucus containing the spores.

Clathrus, Mich., Gen. p. 214; Fischer, Ueber die Phalloideen, p. 66.

The peculiar structure of the receptacle, consisting of a hollow sphere, with the walls forming an irregular network, characterises the genus.

Clathrus cancellatus, Tournef. (Fig. 46). Receptacle sessile, obovate, vermilion, or dingy red, covered with olive mucus containing the cylindrical colourless spores, 3–5 × 2 μ.

Clathrus cancellatus, Tournef.; Hussey, i, t. 86; Berk., Outl. p. 298; Cke., Hdbk. n. 1067; Fisch., Ueber die Phalloideen, p. 73; Wint., Kr. Fl. 870.

Clathrus volvaceus, Bull., Champ. t. 441.

Clathrus ruber, Quel., Enchirid. 235.

Exs.—Rab., Fung. Eur. 35.

Rare. Torquay! Bournemouth! Babbicombe! Isle of Wight! South of Ireland! Windsor!—Europe; United States; Cuba; Jamaica; Antibes; Ceylon; Himalayas.

Resembling *Ithyphallus* before the rupture of the volva. A very beautiful plant, but extremely foetid.

[ASEROE, La Billard.

Receptacle stipitate, expanded at the apex into a horizontal disc with the margin laciniate, spore-bearing mucus situated on the disc.

Aseroe rubra, La Bill., stem red or pale rose, pervious at the

apex, which is expanded into a bright red disc furnished at the margin with from 5–8 bifid rays. Sacc., Syll. vii, p. 25.

An Australian species, that has occurred at Kew in soil brought from Australia.]

GENERA EXCLUDED.

Polyangium, which is of insect origin.

Cenococcum, is probably a degraded genus more allied to the *Tuberaceae.*

EXPLANATION OF THE FIGURES IN PLATES I, II, III, and IV.

Illustrating Mr. George Massee's Monograph on the British *Gastromycetes.*

PLATE I.

Figs. 1–1 *e*. *Hymenogaster tener*, Berk. 1, plants, nat. size; 1 *a*, section, nat. size; *a*, peridium; *b*, the white lines are the tramal plates from which the hymenial elements originate and project into the cavities *c*; *d*, sterile basal stratum; 1 *b*, spores in various stages of development (× 400); 1 *f*, young basidium bifurcating at the apex to form the two spores (× 400); 1 *c*, 1 *d*, 1 *e*, examples of basidia with spores in various stages of development at 1 *e*, nearly mature (× 400). (Drawn from type specimens in Herb. Berk., Kew.)

Figs. 2–2 *c*. *Octaviania asterosperma*, Vitt. 2, plant, nat. size; 2 *a*, section showing portion of gleba, slightly ×; *a*, peridium; *b*, trama; *c*, hymenial cavities; 2 *b*, spores (× 400); 2 *c*, portion of hymenium with basidia and paraphyses (× 200).

Fig. 3. *Octaviania Stephensii*, Tul. Spores (× 400).

Figs. 4–4 *b*. *Hysterangium nephriticum*, Berk. 4, plants, nat. size, showing the dense white felted mycelium; 4 *a*, section, nat. size; 4 *b*, spores (× 400). (Drawn from type specimens in Herb. Berk.)

Figs. 5–5 *b*. *Melanogaster ambiguus*, Tul. 5, plant, nat. size; 5 *a*, section of portion of gleba, slightly ×; 5 *b*, spores (× 400).

Figs. 6, 6 *a*. *Hydnangium carotaecolor*, Berk. 6, plant, nat. size; 6 *a*, two basidia, one bisporous, the other tetrasporous (× 400). (Drawn from type specimens in Herb. Berk.)

Figs. 7, 7 *a*. *Rhizopogon rubescens*, Tul. 7, plant, nat. size; 7 *a*, spores (× 400).

8–8 *b*. *Hymenogaster citrinus*, Vitt. 8, plant, nat. size; 8 *a*, immature apex of a basidium bearing two spores still surrounded by the hyaline sac (× 400); 8 *b*, mature spores (× 400).

Fig. 9. *Rhizopogon luteolus*, Fr. Spores (× 400.)

Fig. 10. *Melanogaster variegatus*, Tul. Spores (× 400).

Fig. 11. *Melanogaster Broomeianus*, Berk. Basidia and spores (× 400). (Drawn from type in Herb. Berk., Kew.)

Fig. 12. *Octaviania compacta*, Tul. Spores (× 400).

Fig. 13. *Hymenogaster vulgaris*, Tul. Spores (× 400).

Fig. 14. *Hydnangium carneum*, Wallr. Spores (× 400).

Fig. 15. *Hymenogaster olivaceus*, Vitt. Spores (× 400).

Fig. 16. *Hymenogaster olivaceus*, Vitt. Var. *modestus* (× 400). (Drawn from type specimens in Herb. Berk.)

Fig. 17. *Hymenogaster pallidus*, B. and Br. Spores (× 400). (Drawn from type specimen in Herb. Berk., Kew.)

Fig. 18. *Hymenogaster luteus*, Vitt. Spores (× 400).

Fig. 19. *Hymenogaster griseus*, Vitt. Spores (× 400).

Fig. 20. *Hymenogaster muticus*, B. and Br. Spores (× 400). (Drawn from type specimens in Herb. Berk.)

Figs. 21, 21 *a*. *Hymenogaster pusillus*, B. and Br. 21, plants nat. size; 21 *a*, various forms of basidia with spores (× 400). (Drawn from type specimens in Herb. Berk.)

Fig. 22. *Hymenogaster decorus*, Tul. Spores (× 400). (Drawn from authentic specimens sent by Tulasne to Berkeley, and now in Herb. Berk.)

Figs. 23, 23 *a*. *Hymenogaster decorus*, Tul. 23, portion of hymenium showing various forms of basidia and sterigmata (after Tulasne, Fung. Hypog., t. x, f. ix, 2); 23 *a*, a basidium bearing a single spore (× 400).

Fig. 24. *Hymenogaster Klotzschii*, Tul. Spores (× 400). (Drawn from the original specimens collected by Klotzsch near Glasgow, now in Herb. Berk.)

Fig. 25. *Hymenogaster Thwaitesii*, B. and Br. Spores (× 400).

Figs. 26, 26 *a*. *Lycoperdon Cookei*, Mass. 26, section of plant, nat. size; 26 *a*, spores (× 400), the larger ones (× 1000). (Drawn from type in Herb., Kew.)

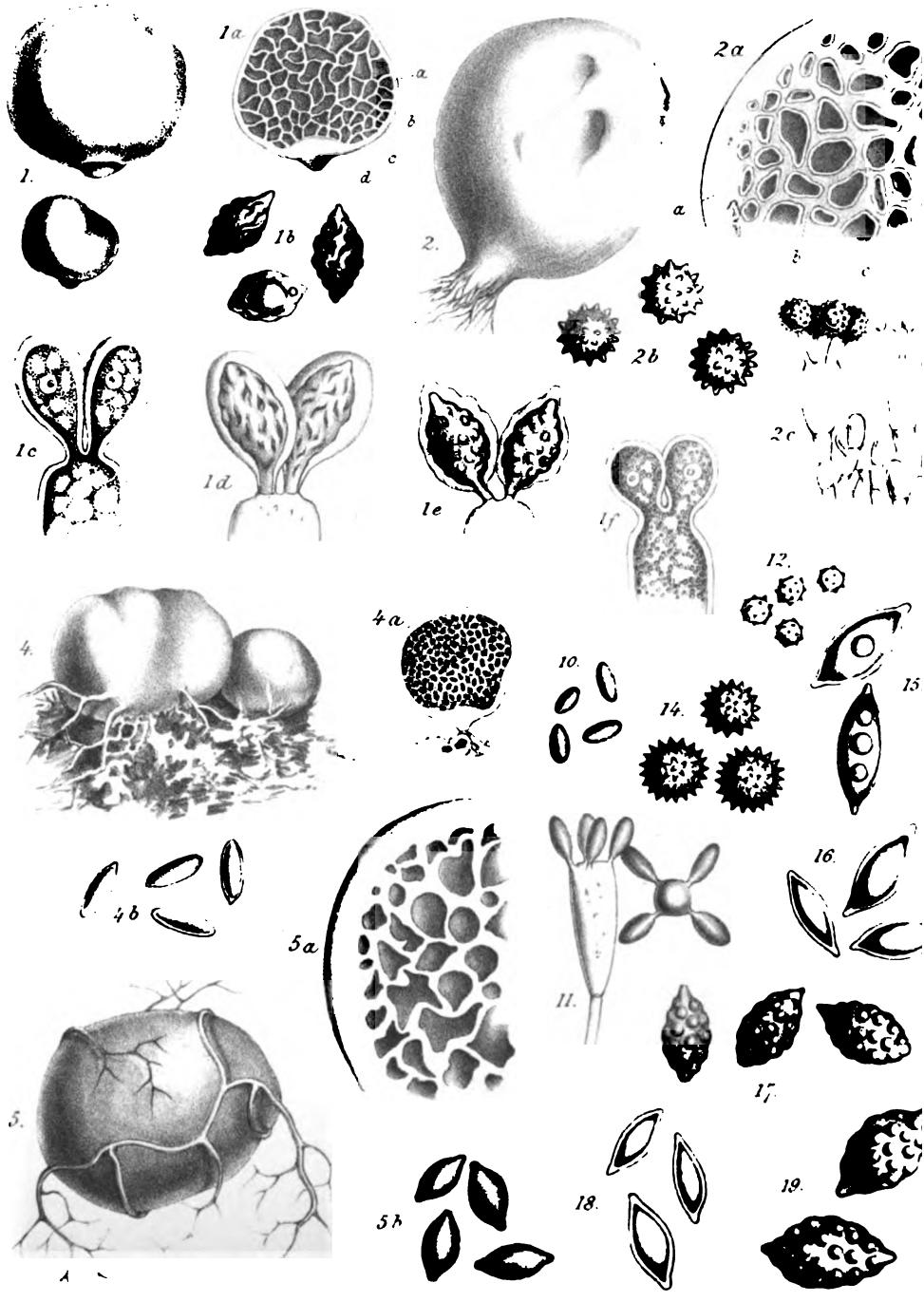
Figs. 27, 27 *a*. *Geaster Michelianus*, W. G. Smith. 27, section of fully developed plant before the rupture of the exoperidium; *a*, *b*, exoperidium, consisting of *a*, an outer brown fibrous coat, lined by a white layer, *a'*, together constituting the fibrillose layer; *b*, the collenchyma-layer; *c*, split-layer; *d*, endoperidium; *e*, columella; *f*, gleba, nat. size; 27 *a*, spores (× 400). (Drawn from authentic specimens from W. G. Smith, now in Herb., Kew.)

Figs. 28, 28 *a*. *Geaster striatus*, D. C. 28, mature plant with the exoperidium expanded; *a*, exoperidium; *b*, endoperidium; *c*, peristome, nat. size; 28 *a*, spores (× 400).

PLATE II.

Figs. 29, 29 *b*. *Battarrea phalloides*, Pers. 29, plant, nat. size; *a*, volva; *b*, portion of volva carried up on the peridium; *c*, peridium; *d*, stem or receptaculum; 29 *a*, spores (× 400); 29 *b*, elongated cells containing spiral or annular thickenings, forming the scanty capillitium; *a*, the original point of attachment of the cell to a hypha (× 400). (Drawn from a specimen collected in Kent.)

Figs. 30, 30 *a*. *Lycoperdon gemmatum*, Batsch. 30, plant, nat. size; *a*, peridium; *b*, sterile stem-like base; 30 *a*, spores (× 400), the large one × 1000.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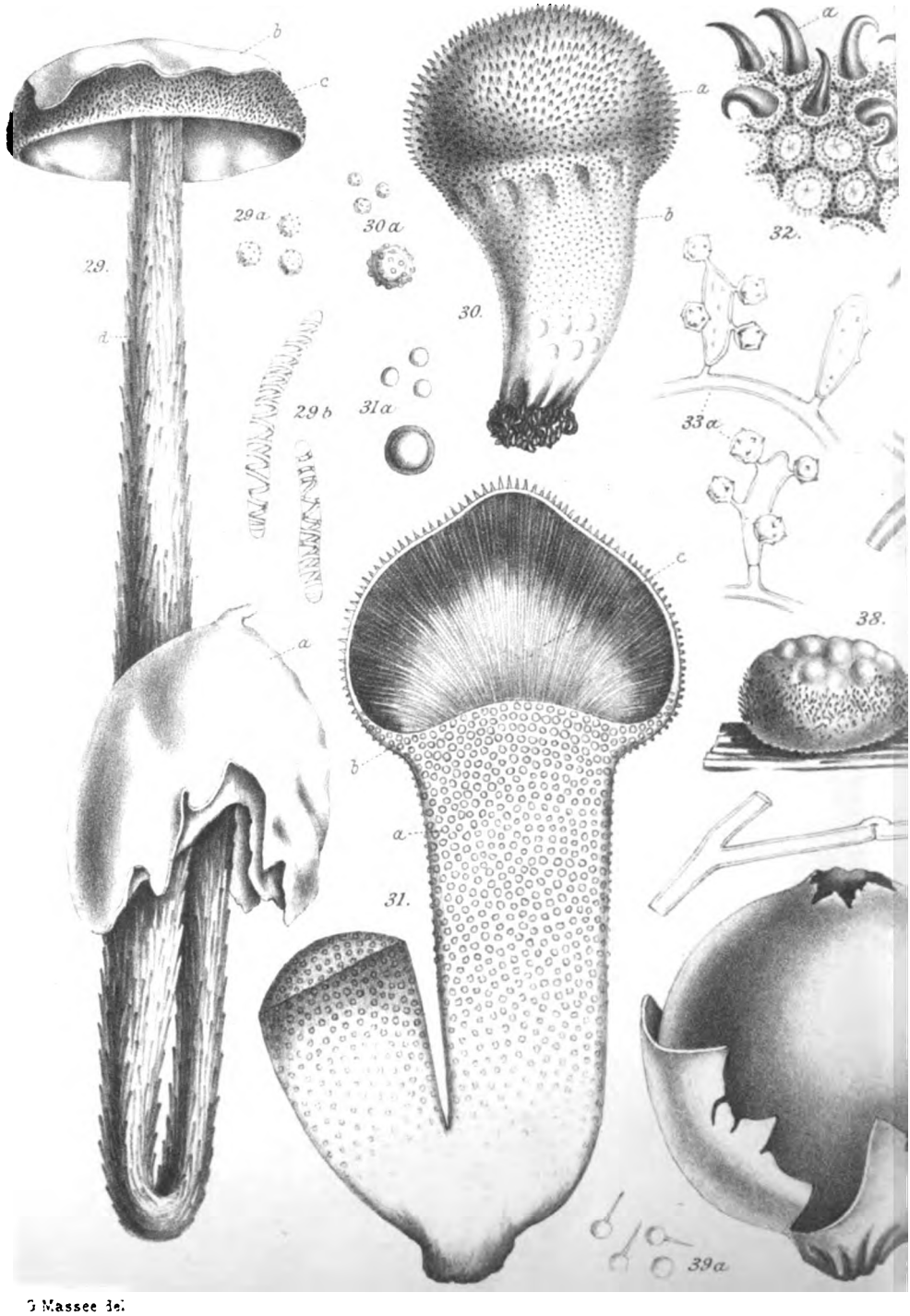

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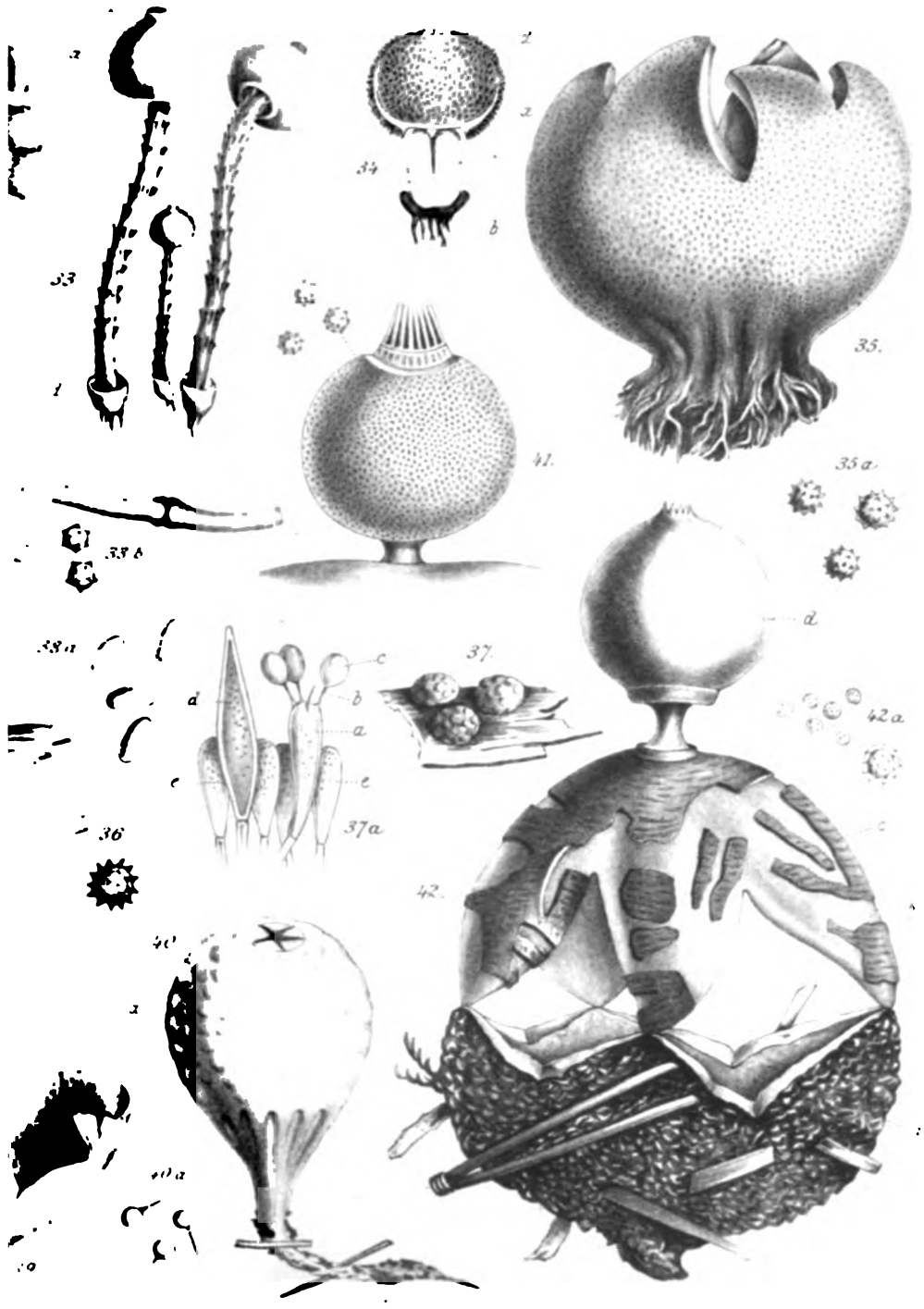
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Figs. 31, 31 *a*. *Lycoperdon perlatum*, pers. 31, plant, nat. size; *a*, cellular stem-like base; *b*, peridium; *c*, capillitium from which the spores have been blown away; 31 *a*, spores (× 400), the large one × 1000.

Fig. 32. *Lycoperdon echinatum*, Pers. Portion of external surface of peridium slightly ×; *a*, spines; *b*, small persistent warts arranged round the spines; *c*, smooth scars on surface of inner layer of peridium from where the spines have fallen away.

Figs. 33–33 *b*. *Tulostoma mammosum*, Fr. 33, group of plants, nat. size; *a*, peridium; *b*, the umbonate mouth or ostiolum; *c*, elongated stem-like base of peridium; *d*, basal remains of the external sheath of stem which is ruptured at the commencement of elongation of the axial portion; 33 *a*, basidia with lateral spores (× 400), after Schröter, Cohn's Beitr. ii, p. 66; 33 *b*, spores and portion of a thread from the capillitium showing the swollen septum (× 400).

Fig. 34. *Tulostoma mammosum*, Fr. Median longitudinal section, nat. size; *a*, peridium; *b*, basal portion of peridium ruptured by the elongation of the axial portion, *c*, of the stem-like base; *d*, gleba. (After Vittadini.)

Figs. 35, 35 *a*. *Scleroderma geaster*, Fr. Mature specimen after dehiscence of the peridium, showing the irregularly stellate opening; 35 *a*, spores (× 400).

Fig. 36. *Scleroderma bovista*, Fr. Spore and portion of capillitium thread showing a transverse septum with clamp-connection (× 400).

Figs. 37, 37 *a*. *Nidularia pisiformis*, Tul. A group of plants, nat. size; 37 *a*, portion of hymenium; *a*, basidium; *b*, one of the four sterigmata; *c*, spore; *d*, cystidium; *e*, *e*, paraphyses (× 400).

Figs. 38, 38 *a*. *Nidularia Berkeleyi*, Mass. 38, plant (× 15); 38 *a*, spores (× 400). (Drawn from type in Herb. Berk.)

Figs. 39, 39 *a*. *Bovista nigrescens*, Pers. 39, plant, nat. size; *a*, inner persistent layer of peridium; *b*, outer evanescent layer of peridium; 39 *a*, spores with the persistent sterigmata (× 400).

Figs. 40, 40 *a*. *Bovista ammophila*, Lev. 40, plant, nat. size; 40 *a*, spores (× 400).

Fig. 41. *Geaster Berkeleyi*, Mass. Inner peridium, nat. size. (From type in Herb. Berk.)

Figs. 42, 42 *a*. *Geaster fornicatus*, Fr. 42, a mature well-grown specimen, nat. size; *a*, outer brown portion of fibrillose layer; *b*, inner white portion of fibrillose-layer; *c*, ruptured collenchyma-layer; *d*, inner peridium; 42 *a*, spores (× 400), the larger one × 1000.

PLATE III.

Figs. 43, 43 *c*. *Mutinus caninus* (Fr.), Fischer. 43, mature plant; *a*, volva; *b*, receptaculum; *c*, sporiferous portion, nat. size; 43 *a*, section of plant before the rupture of the volva, nat. size; 43 *b*, section through apical sporiferous portion of the receptaculum, nat. size; 43 *c*, spores (× 400).

Figs. 44, 44 *d*. *Ithyphallus caninus* (Fr.), Fischer. 44, mature plant, nat. size; *a*, volva; *b*, receptaculum; *c*, 'pileus' after removal of the olive mucus containing the spores; *d*, perforate apex of the receptaculum; 44 *a*, section through apical portion of receptaculum, *a*; *b*, 'pileus,' nat. size; 44 *c*, compressed cavities, as seen in the wall of the receptaculum while yet within the volva (× 3); 44 *b*, median longitudinal section of young plant before the rupture of the volva; *a*—*c*,

volva; *a*, outer layer; *c*, inner layer; *b*, central mucilaginous layer; *d*, gleba; *e*, one of the ribs of the 'pileus,' which form the polygonal elevations on its peripheral surface; *f*, receptaculum; *g*, cord-like mycelium, nat. size; 44 *d*, basidia and spores (× 400).

Figs. 45, 45 *b*. *Scleroderma vulgare*, Fr. 45, plant, nat. size; 45 *a*, median longitudinal section; *a*, peridium; *b*, thickened sterile base of peridium; *c*, gleba; *d*, whitish tramal plates, nat. size; 45 *b*, spores (× 400).

Figs. 46, 46 *b*. *Clathrus cancellatus*, L. 46, mature expanded plant; *a*, volva ruptured in an irregularly stellate manner; *b*, receptaculum from which the mucus has been removed; 46 *a*, basidia and spores (× 400).

Fig. 47. *Scleroderma verrucosum*, P. Spores (× 400).

Figs. 48, 48 *a*. *Cyathus striatus*, Hoffm. 48, a group of plants (× about twice); 48 *a*, a peridiolum with its funiculus; *a*, peridiolum in median longitudinal section; *b*—*d*, funiculus; *b*, hollow thickened portion cut open to show the coil of hyphae, *e*, *e'*, contained in its interior, which has been stretched out at *e*; *c*, central constricted isthmus-like portion of funiculus; *d*, basal thick portion which is attached to the wall of the peridium, × (after Tulasne, Ann. Sci. Nat., sér. 3, vol. i).

Fig. 49. *Cyathus vernicosus*, D. C. Peridiolum, *a*; funiculus, *b*; portion of inner wall of peridium to which the funiculus is attached, *c* (× 40).

Fig. 50. *Cyathus vernicosus*, D. C. Median longitudinal section through a peridiolum; *a*, outer brown fibrous layer; *b*, inner dense tramal wall from which the hymenial elements originate and project into the central cavity, *c*; *d*, portion of funiculus (× 50).

Figs. 51, 51 *a*. *Cyathus vernicosus*, D. C. 51, group of plants, nat. size; *a*, peridium; *b*, peridiolum; 51 *a*, spores (× 400).

Figs. 52–52 *b*. *Crucibulum vulgare*, Tul. 52, group of plants, nat. size; 52 *a*, peridiolum with its funiculus (× 40); 52 *b*, spores (× 400).

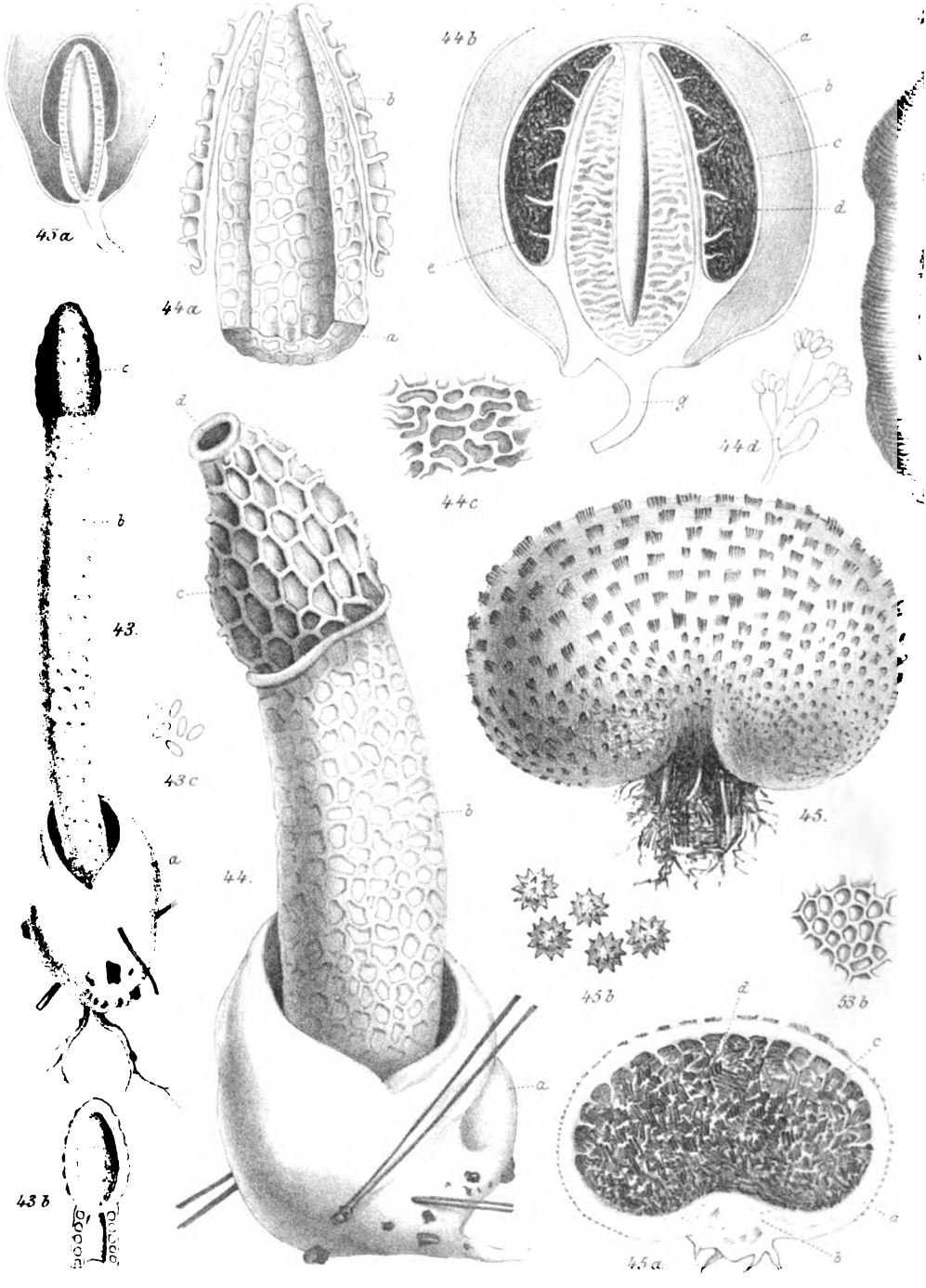
Figs. 53, 53 *b*. *Polysaccum pisocarpium*, Fr. 53, plant, nat. size; 53 *a*, spores (× 400); 53 *b*, portion of gleba showing tramal plates, nat. size.

PLATE IV.

Fig. 54. *Hymenogaster tener*, Berk. Section through a portion of the peridium and gleba; *a*, *a*, central portion of tramal plates showing the hyphae running more or less parallel to the walls of the cavities; *b*, *b*, hymenial elements consisting of basidia and paraphyses, which originate from the central hyphae of the tramal plates; *c*, *c*, spores; *d*, *d*, cavities of the gleba; *e*, outer surface of peridium (× 80).

Figs. 55–55 *c*. *Sphaerobolus stellatus*, Tode. 55, diagrammatic median longitudinal section before rupture of the peridium; *m*, mycelial-layer; *p*, pseudo-parenchyma-layer; *f*, split-layer; *c*, collenchyma-layer; *s*, gleba; 55 *a*, diagrammatic median longitudinal section after the rupture of the peridium at the apex, letters same as in Fig. 55; 55 *b*, diagrammatic median longitudinal section after extrusion of the collenchyma-layer and split layer, and ejection of the gleba, letters as in Fig. 55 (after Fischer, Bot. Ztg. 1884); 55 *c*, basidia and spores (× 400).

Figs. 56, 56 *a*. *Geaster Bryantii*, Berk. 56, endoperidium, nat. size; 56 *a*, spores (× 400), the large one × 1000, (drawn from type specimen in Herb. Berk, Kew).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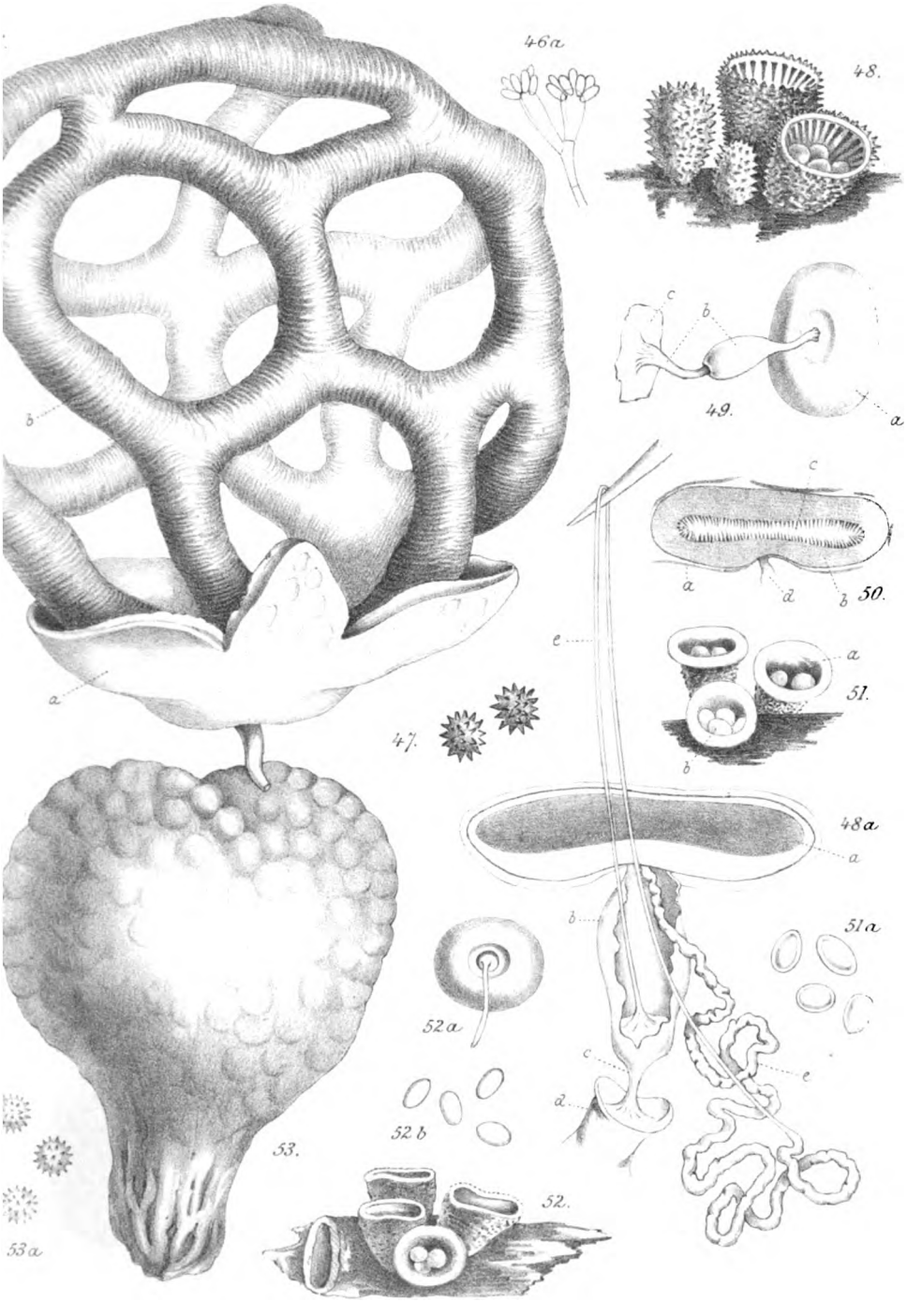

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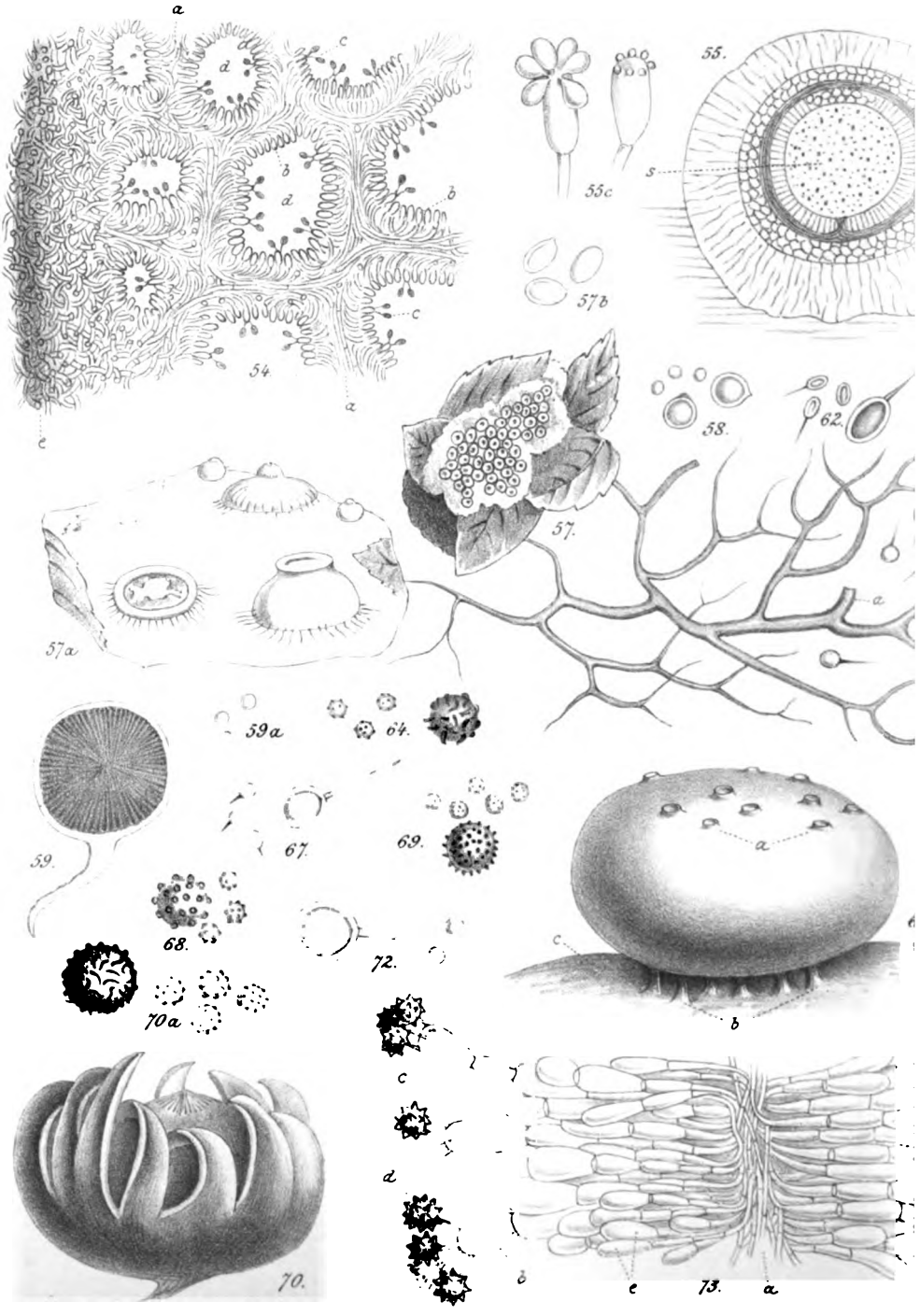

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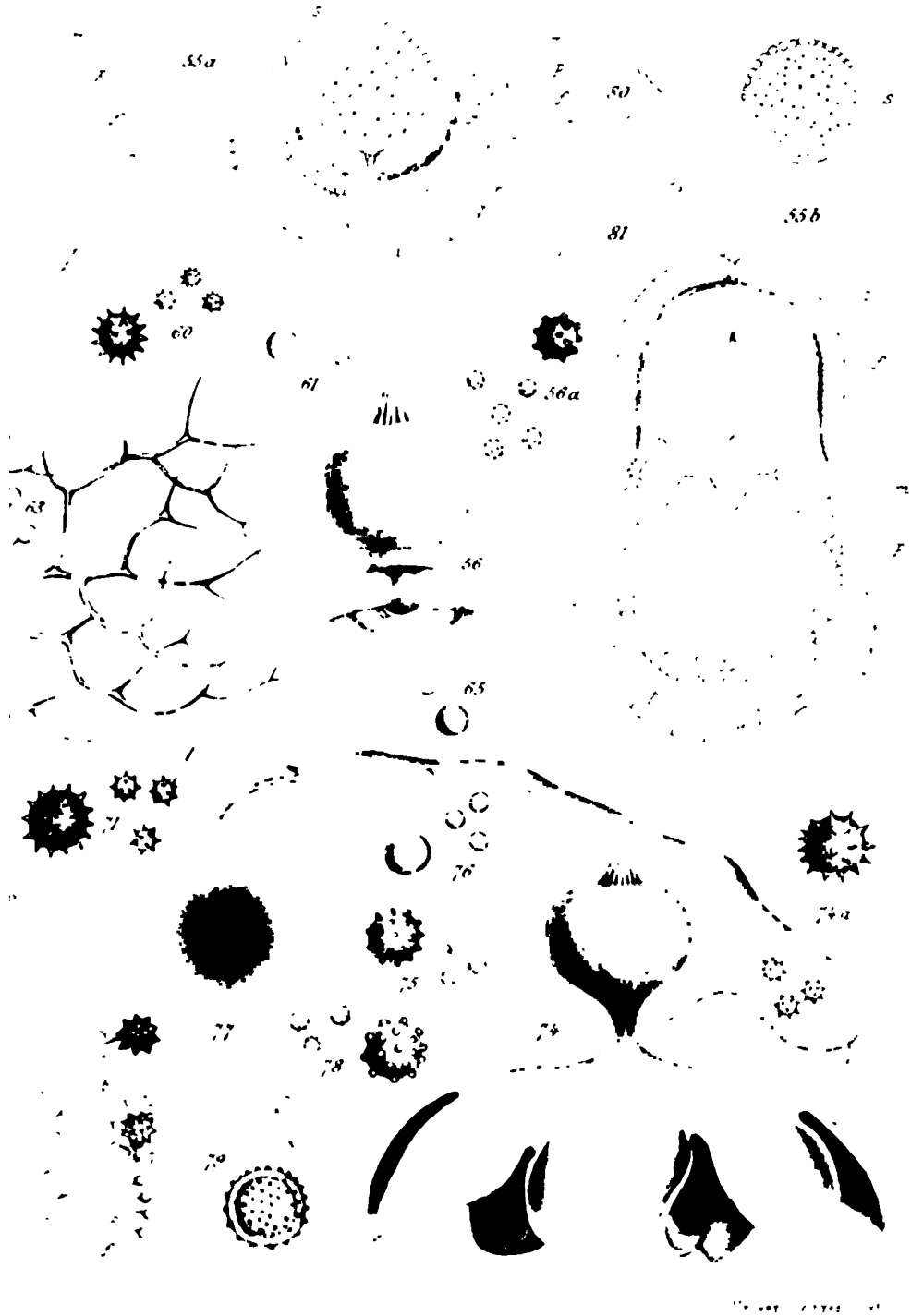
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Figs. 57–57 *b*. *Thelebolus terrestris*, Alb. and Schw. 57, a group of plants, nat. size; 57 *a*, plants in various stages of development, × (after Albertini and Schweinitz, Cons. Fung. t. ii, f. iv); 57 *b*, basidia and spores (× 400).

Fig. 58. *Lycoperdon coelatum*, Bull. Spores (× 400,) the large one × 1000.

Figs. 59, 59 *a*. *Bovista pusilla* (Fr.), De Toni. 59, median longitudinal section of plant, nat. size; 59 *a*, spores (× 400).

Fig. 60. *Lycoperdon saccatum*, Vahl. Spores (× 400), the large one (× 1000).

Fig. 61. *Lycoperdon pyriforme*, Schaeff. Spores (× 400), the large one × 1000.

Fig. 62. *Bovista ovalispora*, Cke. and Mass. Spores (× 400), the large one × 1000, drawn from type specimen in Herb., Kew).

Fig. 63. *Bovista plumbea*, Pers. Spores (× 400), and branched thread of capillitium (× 150); *a*, point of attachment of the thread to the parent hypha.

Fig. 64. *Lycoperdon excipuliforme*, Scop. Spores (× 400), large one × 1000.

Fig. 65. *Lycoperdon molle*, Pers. Spores (× 400), the large one (× 1000).

Fig. 66. *Geaster coliformis*, Pers. Endoperidium, nat. size; *a*, apertures surrounded by a rudimentary peristome; *b*, pedicels supporting the endoperidium and springing from the exoperidium *c*, the upper portion only of which is represented.

Fig. 67. *Bovista olivacea*, Cke. and Mass. Spores (× 400), the large one × 1000 (drawn from type specimen in Herb. Brit. Mus.).

Fig. 68. *Lycoperdon Hoylei*, Berk. Spores (× 400), the large one (× 1000), (drawn from type specimens in Herb. Berk., Kew.)

Fig. 69. *Geaster limbatus*, Fr. Spores (× 400), large one × 1000.

Figs. 70, 70 *a*. *Geaster hygrometricus*, Pers. 70, plant, nat. size, with the exoperidium split and the rays incurved (as is the case when the plant is dry); 70 *a*, spores (× 400), large one (× 1000).

Fig. 71. *Lycoperdon atropurpureum*, Vitt. Spores (× 400), large one × 1000.

Fig. 72. *Bovista cepaeforme*, Bull. Spores (× 400), large one × 1000.

Fig. 73. *Octaviania asterosperma*, Vitt. Portion of gleba; *a*, central hyphae of the trama; *b*, basidium; *c*, sterigmata; *d*, spores; *e*, paraphyses; *f*, basidium with four very young spores (× 200).

Figs. 74, 74 *a*. *Geaster Schmideli*, Vitt. 74, mature plant, nat. size; 74 *a*, thread from capillitium and spores (× 400), the large spore × 1000.

Fig. 75. *Geaster lageniformis*, Vitt. Spores (× 400), the large one × 1000.

Fig. 76. *Lycoperdon bovista*, Linn. Spores (× 400), the large one × 1000.

Fig. 77. *Geaster fimbriatus*, Fr. Apex of exoperidium showing the peristome, nat. size.

Fig. 78. *Geaster mammosus*, Chev. Spores (× 400), the larger one × 1000.

Fig. 79. *Geaster rufescens*, Pers. Spores (× 400), large one (× 1000).

Fig. 80. *Hysterangium Thwaitesii*, B. and Br. Spores × (400).

Fig. 81. *Nidularia confluens*, Fr. Spores (× 400). (Drawn from an authentic specimen sent by Fries to Berkeley.)

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INDEX.

Specific names in italics are those accepted in the text for the species described, and if a described species is referred to on more than one page the figure in italics indicates the page at which the description will be found.

ACTINODERMIUM, 76.
AGARICUS, 3.
ANTHURUS, 30.
ARACHNION, 30.
AREOLARIA, 30.
ARGYLIUM, 35.
— liquaminosum, 35.
ASEROE, 21, 30, *90.*
— rubra, 90.

BATTARREA, 5, 18, 30, *86.*
— *phalloides*, 15, *87.*
— steveni, 18.
Boletus, 22, 23.
BOVISTA, 6, 15, 16, 30, *62.*
— *ammophila*, 64.
— *cepaeforme*, 65.
— gigantea, 75.
— *nigrescens*, 63.
— officinalis, 74.
— *olivacea*, 64.
— *plumbea*, 63.
— *pusilla*, 29, *65.*
BROOMEIA, 30.

CALATHISCUS, 30.
CALICIOCARPUS, 30.
CALOSTOMA, 5, 29, 30.
CALVATIA, 30.
CASTOREUM, 30.
CAULOGLOSSUM, 30.
CENOCOCCUM, 91.
CLATHRUS, 30, *90.*
— *cancellatus*, 28, *90.*
— ruber, 90.
— volvaceus, 90.
COILOMYCES, 30.
COLUS, 30.
— hirundinosus, 28.
CORTICIUM, 2.
CRUCIBULUM, 3, 12, 13, 30, *56.*
— *vulgare*, 56.
CYATHUS, 7, 12, 30, *53.*
— campanulatus, 55.
CYATHUS. crucibulum, 57.
— crucibuliformis, 57.
— cylindricus, 57.
— laevis, 55, 57.
— olla, 55.
— *striatus*, 12, *54.*
— *vernicosus*, 55.
— —, var. *agrestis*, 56.
CYCLODERMA, 17, 30.
CYNOPHALLUS, 89.

DACRYOBOLUS, 30.
DENDROMYCES, 86.
DICTYOPHORA, 30.
DIPLOCYSTIS, 30.
DIPLODERMA, 30.
DIPLODERMEAE, 62.

ELAPHOMYCEI, 26.
ELAPHOMYCES, 9, 26, 27.
ERIOSPHÆRIA, 30.

FAVILLEA, 30.

GASTROMYCETES, 1, 25, 29.
GAUTEIRA, 3, 29.
GEASTER, 5, 14, 16, 30, *76.*
— Archeri, 85.
— *Berkeleyi*, 79.
— *Bryantii*, 77.
— —, var. *minor*, 78.
— *coliformis*, 77.
— coronatum, 79.
— *fimbriatus*, 17, *81.*
— *fornicatus*, 14, 17, *80.*
— *hygrometricus*, 6, 16, 17, *83.*
— *lageniformis*, 84.
— *limbatus*, 79.
— *mammosus*, 81.
— *Michelianus*, 84.
— multifidum, 79.
— orientalis, 78.
GEASTER, Rabenhorstii, 78.
— radicans, 80.
— *rufescens*, 82.
— *Schmideli*, 78.
— *striatus*, 85.
GEASTRUM, 80.
— quadrifidum, 80.
GLISCHRODERMA, 30.
GLOBARIA, 62.
— furfuracea, 65.
— nigrescens, 63.
— plumbea, 64.
— pusilla, 66.
GLOBULARIA, 75.
— gigantea, 75.
GRANULARIA, 58.
— pisiformis, 58.
GYROPHRAGMIUM, 30.

HIPPOPERDON, 30.
HYDNANGIUM, 29, *36.*
— *carneum*, 37.
— *carotæcolor*, 36.
— Stephensii, 32.
HYMENANGIUM, 21.
— virens, 21.
— album, 42.
HYMENOGASTREÆ, 8, 25, 29, *31.*
HYMENOGASTER, 9, 11, 27, 28, 29, *41.*
— albus, 42.
— argenteus, 47.
— *citrinus*, 27, *45.*
— *decorus*, 9, 27, *43.*
— *griseus*, 44, *48.*
— *Klotzschii*, 42.
— lilacinus, 47.
— *luteus*, 43.
— *muticus*, 42.
— *olivaceus*, 45.
— —, var. *modestus*, 46.
— *pallidus*, 44.
— populetorum, 45.
— *pusillus*, 48.

HYMENOGASTER, *tener*, 10, 27, *46*.
— *Thwaitesii*, 47.
— *vulgaris*, 44.
HYMENOMYCETES, 1.
HYPERRHIZA, 35.
— liquaminosa, 35.
— tuberosa, 35.
HYPOGAEI, 31.
HYSTERANGIUM, 29, *37*.
— clathroides, 27.
— Duriæanum, 41.
— luteolus, 41.
— *nephriticum*, 37.
— rubescens, 40.
— *Thwaitesii*, 38.

ITHYPHALLUS, 18, 20, 21, 30, *87*.
— impudicus, 8, 19, 28, *88*.

KALCHBRENNERA, 30.

LANGERMANNIA, 75.
— gigantea, 75.
LANOPILA, 30.
LYCOGALOPSIS, 30.
LYCOPERDEAE, 14, 30, *62*.
LYCOPERDON, 6, 15, 16, 19, 21, 30, *66*, 77, 79, 86.
— ardosiacum, 63, 64.
— *atropurpureum*, 68.
— aurantiacum, 50.
— *bovista*, 15, 63, 74, *75*.
— *caelatum*, 74.
— carpobolus, 60.
— capsuliferum, 52.
— cervinum, 50.
— coliforme, 77.
— constellatum, 73.
— *Cookei*, 75.
— coronatum, 80.
— defossum, 51.
— *echinatum*, 67.
— emodense, 29.
— esculentum, 68.
— *excipuliforme*, 69.
— fenestratum, 80.
— fornicatus, 80.
— geaster, 81.
— *gemmatum*, 70, 73, 74.
— —, var. echinatum, 67.
— —, var. excipuliforme, 69.
— —, var. perlatum, 70, 73.
— giganteum, 75.
— globosum, 63.
LYCOPERDON, hirtum, 73.
— *Hoylei*, 68.
— lacunosum, 73.
— mammosum, 86.
— maximum, 75.
— *molle*, 73.
— nigrescens, 63.
— pedunculatum, 80.
— *perlatum*, 72.
— phalloides, 87.
— plumbeum, 64, 65.
— pratense, 65.
— pusillum, 65, 76.
— *pyriforme*, 71.
— —, var. *excipuliforme*, 72.
— quadrifidum, 80.
— quercinum, 68.
— recolligens, 81.
— *saccatum*, 69.
— stellatum, 82, 83.
— verrucosum, 51.
LYSURUS, 30.

MACOWANITES, 29.
MATULA, 3.
MELANOGASTER, 8, 9, 29, *33*.
— *ambiguus*, 34.
— —, var. *intermedius*, 35.
— Berkeleyanus, 40.
— Broomeianus, 34, 40.
— Klotzschii, 35.
— *variegatus*, 33.
— —, var. *Broomeianus*, 34.
MERULIUS, 22.
— lacrymans, 25.
MESOPHELLIA, 30.
MUTINUS, 18, 20, 30, *88*.
— *bambusinus*, 20, *89*.
— *caninus*, 20, 28, *89*.
MYRIOSTOMA, 76.
— coliformis, 77.

NIDULARIA, 30, 53, *57*.
— *Berkeleyii*, 59.
— campanulata, 55.
— *confluens*, 59.
— *dentata*, 59.
— farcta, 59.
— laevis, 57.
— *pisiformis*, 12, *58*.
— —, var. *Broomei*, 58.
— striata, 54.
— vernicosa, 53.
NIDULARIEAE, 11, 12, 30, *53*.

OCTAVIANIA, 29, *31*.
— ambigua, 35.
— *asterosperma*, 11, *31*.
— *compacta*, 32.
— stephensii, *31*, 32.
— variegata, 33.

PAUROCOTYLIS, 30.
PENIOPHORA, 2.
PEZIZA, 54.
— hirsuta, 54.
— laevis, 57.
— lentifera, 55.
— olla, 55.
— striata, 54.
PHALLOIDEAE, 18, 30, *87*.
PHALLUS, 3, 21, 87.
— bambusinus, 89.
— caninus, 89.
— foetidus, 88.
— inodorus, 89.
— iosmos, 88.
PHELLORINIA, 30.
PHLYCTOSPORA, 27.
PISOCARPIUM, 52.
— arenarium, 53.
PISOLITHUS, 52.
— arenarius, 53.
PLECOSTOMA, 80.
— fornicatum, 80.
PODAXINEÆ, 30.
PODAXON, 7, 30.
POLYANGIUM, 91.
POLYERA, 52.
POLYGASTER, 30.
POLYPLOCIUM, 22, 23, 30.
POLYPORUS, 25.
— betulinus, 24.
— obvallatus, 23.
— volvatus, 23, 24.
POLYSACCUM, 4, 11, 30, *52*.
— acaule, 52.
— arenarium, 52.
— olivaceum, 52.
— *pisocarpium*, 52.
— uliferum, 52.
POMPHOLYX, 49.
— sapidum, 49.

QUELETIA, 30.

RHIZOPOGON, 8, 29, *39*.
— albus, 40, 42.
— *luteolus*, 27, *40*.
— *rubescens*, 39.

SCLERODERMA, 5, 19, 30, *49*.

SCLERODERMA, *bovista*, 51.
— *geaster*, 51.
— *verrucosum*, 11, *50*.
— *vulgare*, 49.
SCLERODERMEAE, 11, 30, *49*.
SCOLECIOCARPUS, 30.
SECOTIUM, 22, 23, 30.
— erythrocephalum, 23.
SIMBLUM, 30.
SPARASSIS, 23.
SPHÆRICEPS, 30.
SPHÆROBOLUS, 3, 13, 14, 30, 53, *60*.
— *stellatus*, 13, *60*.
SPLANCHNOMYCES, 41.
SPLANCHNOMYCES, citrinus, 45.
— luteus, 43.
— membranaceus, 39.
— tener, 44.
STEREUM, 3.

THELEPHORA, 3.
THELOBOLUS, 14, 30, *61*.
— *terrestris*, 61.
TRICHASTER, 30.
TRICHOGASTRES, 62.
TUBER, 26.
— moschatum, 33, 34.
— virens, 41.
TUBERACEÆ, 26.
TULASNODEA, 85.
TULOSTOMA, 4, 5, 7, 18, 30, *85*.
— brumale, 86.
— *mammosum*, 86.
TYLOSTOMA, 85.

UTRARIA, 66.
— atropurpurea, 69.
— caelata, 74.
— echinata, 67.
— excipuliforme, 69.
— gemmata, 71.
— pyriformis, 72.
— saccata, 70.

XYLOPODIUM, 30.

On a change of Flowers to Tubers in Nymphaea Lotus, var. monstrosa.

BY

C. A. BARBER, B.A.

Scholar of Christ's College, Cambridge; Demonstrator of Botany in the University of Cambridge.

With Plate V.

AMONG the plants of *Nymphaea* in the Water-lily House at Kew there is a specimen brought from Lake Nyassa by Sir John Kirk in 1886, which shows great abnormality in the formation of its flowers.

In the first summer after its introduction, it flowered in a normal manner, and was determined by Professor Oliver to be a white-flowered variety of *Nymphaea Lotus*. It was accordingly distinguished from the other numerous varieties of the species by the name *flore albo* [1].

Mr. Watson of Kew Gardens tells me that, while the first formed flower-buds were developing into the normal blooms, a further and very large development of buds took place, suggesting that the variety would turn out to be of value for horticultural purposes. These buds were, however, slow of growth, and, upon examination, it was found that they were curiously deformed. The sepals, which appeared as usual, were not followed in due course by petals and stamens,

[1] Owing to the peculiarities subsequently to be described, I think it better to follow Mr. Watson's suggestion, and to call the plant by the varietal name *monstrosa*.

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but were found to enfold a number of green leaves with occasional buds in their axils, separated from one another, and almost concealed from view, by a dense mass of long white hairs. This formation of foliage instead of floral leaves, accompanied as it was by a great swelling of the end of the axis of the flower, may be briefly described by saying that tubers were developed in place of flowers.

During the year 1888 no flowers were produced, but all the buds were developed in the same curious manner. Mr. Gardiner collected a large bottle of the buds in various stages of development, and I was able subsequently to examine the plant for myself, and to obtain further specimens of tubers from the tank in the living state. These were transferred to the Lily-House at Cambridge, and have developed there into plants similar to the parent form, and bearing the same deformed flowers.

I gladly take this opportunity of thanking Mr. Watson for his willing assistance in affording me access to the plant, and in giving me all the information in his power concerning it.

Description of Specimens.

As will be seen in the Plate (Fig. 1), the first appearance of the flower-bud is fairly normal. The calyx-leaves, of which sometimes only three are present, are developed as usual; and, as long as they can enclose the swelling receptacle and leaves growing upon it, the bud might be regarded as that of a normal flower. Upon tearing away the sepals, however, a number of green leaves are exposed, surrounded and concealed at their bases by dense masses of white hairs (Fig. 2). In order further to investigate these leaves, the hairs must be cleaned away; and, as some of the younger leaves are sometimes carried away with them, the operation requires some care. Fig. 3 shows the same bud cleaned of hairs and divided longitudinally [1].

[1] The number of sepal-like leaves, with broad sheathing bases, is by no means constant in the different buds. Thus, in four buds from Kew, there were 3, 3, 3,

As the bud increases in size, the calyx-leaves cease to grow in breadth, and become distorted, presenting an appearance which suggests that some injury may have been sustained by the plant (Fig. 4). Upon removing the calyx-leaves and hairs in this specimen, the form of the new leaves is well seen (Fig. 5). The lamina and petiole are those of ordinary foliage-leaves, and the eared leaf-base corresponds exactly with that in the leaves of *Nuphar*. From the base of each leaf are protruding several adventitious roots. As will be gathered from the figure, the expanded leaf-bases form an excellent protection for the younger parts.

Fig. 6 represents a series of leaves from one bud. At *g* the leaf-base is well developed, and bears at its apex the small point which is the rudiment of the lamina. At *e* the lamina is already becoming formed; and *d* to *a* show the intercalation of petiole between leaf-base and upper leaf. The arrangement of these leaves, as far as can be followed, appears to be identical with that of the parts of the normal flower-bud. The sepals exhibit the same aestivation as is usual in *Nymphaea*-flowers: one is quite exterior, the one opposite quite interior, and the lateral ones are half covered, half covering. The sepals are followed by a whorl of foliage-leaves alternating with them, and, inside these, a second whorl alternating with the last. The rest of the elements could not be satisfactorily determined, because of the presence of buds which appeared to disturb the order. In *Nymphaea alba* the eight petals following the sepals form the first

and 5 sepaloid leaves respectively, before the foliage-leaves commenced: in two buds borne by one of the plants figured (see Figs. 13, 15), the numbers were 4 and 8: while in three buds from a luxuriant specimen imported from Kew and growing at Cambridge, the numbers reached 10, 12, and 16 respectively. In these last buds the inner 'sepals' showed some similarity to petals, in fact might almost be regarded as petals which had turned green. And, just as in the normal *Nymphaea* flower there is a transition from petals to stamens, so, in many of these specimens, there may be traced a series of stages between the sheathing sepaloid leaves and the foliage leaves. In other specimens, and notably so in the one here figured (Figs. 4, 5), the leaves immediately following the calyx are markedly different from the sepals, and readily divisible into the leaf-base, petiole, and lamina of foliage-leaves.

members of ascending spirals, and it is possible that a similar arrangement of parts is to be met with in this case[1].

Fig. 7 shows an older bud from which all the sepals but one have fallen. Some of the foliage-leaves have also been cut off, but one remains to show that they are perfect in their formation. Strong adventitious roots of great length are given off from the bud, having their origin, here, as in Fig. 5, in the leaf-bases[2].

Finally, the whole surface is covered by a dense coating of hairs.

In Fig. 9 is drawn a specimen bearing axillary buds; and in the same specimen may be seen the persistent root-caps of Nymphaeaceous roots[3].

The abundant formation of roots, and the occasional protrusion of buds, may perhaps be associated with the formation of foliage-leaves upon the flower. The leaves no doubt assist in supplying the stores of nutriment which result in the formation of the spherical tuber; but the development of buds, and the unnecessary formation of long adventitious roots, while the bud is still borne on high in the water by the long flower-stalk, appear to be due to incomplete adaptation to surroundings. If one might so express it, the bud does not appear to be quite aware of its abnormal position; and, as soon as it becomes changed to a vegetative shoot, puts forth all the correlated organs which, however, would be of use only in the natural position of such a shoot, namely, in the mud.

The tuber at this stage of development is pushed outwards and downwards by its lengthening stalk; and frequently becomes nearly invisible from the surface of the water, so

[1] Eichler, Blüthendiagramme, ii. 185.

[2] This origin of the roots is not at all abnormal: for it is a well-marked character in the group, that, after the short-lived primary embryonic root has died (Fig. 14), all secondary roots have their origin in the leaf-bases, rarely, if ever, arising from other parts of the stem. It is noteworthy that the sepals, and sepaloid leaves inside them, do not bear adventitious roots arising from their bases. In one case only, a transitional leaf was seen to bear one root (see note on p. 110).

[3] De Bary, Comp. Anat. p. 413.

deep has it plunged over the edge of the flower-pot. The sepals and other leaves now commence to decay; and the stalk becomes rotten and gives way, allowing the tuber to fall to the bottom [1].

The specimen last figured was the oldest in Mr. Gardiner's bottle. On examining the plant at Kew, I dug about in the soil surrounding the rootstock, and found, at various depths, black rounded bodies which, upon cleaning, turned out to be tubers, each with traces of a stalk at one point (Figs. 10, 11, 12). These were evidently the product of the deformed flower-buds under discussion which had dropped into the mud from the decay of the peduncles, all the leaves, buds, and roots, of which traces still remained, having gradually decomposed, and now forming, with the enveloping hairs, a bed of manure for the new plant. Upon cleaning away the hairs from one of the specimens, the apical region was seen to be protected from injury by the fence-like arrangement of the inturned petioles of dead leaves (Fig. 11). This arrangement of petioles was readily observable in some of the older buds still borne on the peduncles: the leaves, whose petioles were thus turned inwards, were an inner circle surrounded by the buds in the axils of the outer leaves.

A longitudinal section through the tuber showed a cup-shaped depression, which contained a bunch of young leaves, closely enveloped in hairs, constituting the apical bud (Fig. 12). Such an arrangement has apparently been brought about by the intercalary growth of a portion of the tuber below the origin of the younger leaves, similar to that

[1] The transitory nature of the leaves and roots developed upon the swelling tuber reminds one of the few small leaves formed on the bulbils on the inflorescence of *Polygonum viviparum* (Drude in Schenk's Handbuch, i. 597), before they are dropped from the parent plant. The shedding of leaves is probably connected with the fact that the species has a period of rest; and the condition of the parent plant, as it approaches its resting state, is probably shared in by the parts cut off to lead an independent existence. In such plants as *Crassula quadrifida*, which, at any rate in our greenhouses, appears to be evergreen, the plantlets, dropped from the inflorescence, take root and grow continuously till they assume the size and form of the parent plant.

occurring in many floral axes, and notably in the inflorescence of the fig.

Fig. 13 represents the germination of one of these tubers. It was planted in November in the Cambridge Gardens and drawn again on March 1. It is of interest to note that the first leaf formed is exactly similar in shape to the first leaf formed in the germination of the seed of the same species. The leaves next following pass very rapidly to the mature form, not, as in the seed, through many gradations. (Cf. Figs. 13 *a*, *b*, *c*, and Fig. 14.) Fig. 15, finally, represents another tuber also drawn on March 1, which shows that the axillary buds, developed among the leaves of the receptacle, do not all perish. One of these buds has put forth a runner, and is developing at a slight distance from the bud of the main axis.

At the date of writing (June 20), the plant of Fig. 13 has attained to a considerable size, and has already borne five buds, all of which are developing into tubers. Three of these present the early appearances of the buds described in this paper. In one, which was found lying on the surface of the soil, at the end of a short peduncle, the four calyx-leaves were attenuated and scale-like, not half enclosing the swelling tuber. Lastly, one specimen was found in the soil, borne by a short peduncle, and presenting a slight resemblance to such a tuber as that of the potato. There was a marked diminution in size of the sepaloid and other leaves growing upon this tuber[1].

Similar Cases in Nymphaea.

Peculiarities of a similar nature have been observed before in *Nymphaea Lotus*. Thus in Masters' Teratology, 1869, the following passage occurs on page 277, under Chloranthy: 'Specimens of *Nymphaea Lotus* have been seen in which all

[1] A month later, on July 17, there appeared upon this same plant, much to my surprise, a full-blown beautiful white flower with the usual characteristics of *N. Lotus*. This is the only case I know of, in which a flower has developed fully, since the early summer of 1887 (see p. 108). No other flower has appeared (Nov. 1889).

the parts of the flower, even to the stigma, were leafy, while the ovules were entirely wanting.'

In the Gardeners' Chronicle, 1885, p. 548, is figured a monstrous specimen of *Nymphaea devoniensis*[1], exhibiting axillary floral prolification. It is described as follows: 'In the aquarium at Syon House, it was observed, a few weeks ago, that the beautiful water-lily, called *N. devoniensis*, had produced a flower, from the midst of which arose another lily, itself hanging gracefully at the end of another stalk. . . . . The new flower proceeded directly from the axil or base of one of the stamens. . . . . But the disturbance of the natural condition of this water-lily was by no means confined to the production of a second flower. On the contrary, it extended to the innermost organs, and forced the very stigmas to grow up into small green leaves folded up as they always are in the young bud.'

In commenting upon this specimen, Masters writes: 'It is curious that among Dr. Kirk's drawings of East African Tropical plants now at Kew, there should be one representing a precisely similar state of things. The species, in both instances, was *N. Lotus*, or a cultivated variety of it[2].'

Lastly, *Nymphaea dentata*, another variety of *Nymphaea Lotus*, is mentioned as one of those few plants in which it is not uncommon for stamens to be changed to ordinary foliage-leaves[3]. Again, phyllody of the pistils, which is a commoner occurrence, is also mentioned as found in this plant[4].

It is perhaps not surprising that peculiarities of this kind should be found more frequently in the varieties of the present species. The plant has been known from time immemorial: it is the sacred Lotus of the Egyptians, and is found painted upon their ancient monuments. It is at present extensively cultivated all over the Old World, and is by far the best known of the water-lilies. Any peculiarities would at once be detected in so valuable an ornamental plant. And probably

[1] A hybrid of *N. Lotus*, obtained from the variety *rubra* crossed with the type, raised at Chatsworth. The Garden, Apr. 14, 1883.

[2] Masters' Terat. p. 143. [3] Ib. 256. [4] Ib. 258.

this very cultivation, and the frequent importation of the plant to climates, such as our own, which are uncongenial to it, and where its perfect development is attended with difficulty, would render it peculiarly liable to deformities of the kind mentioned.

Concluding Remarks.

From the description given, it seems that the case is one of Chloranthy, as defined in Masters' Teratology, p. 273. The author states, 'By Chloranthy it is understood that all, or the great majority, of the organs of a flower assume the form and appearance of foliage-leaves, the calyx not infrequently excepted.' Examples are given from the Rosaceae and Cruciferae, in which families the phenomenon is of most frequent occurrence. It must be pointed out, however, that, in these cases, the malformation must be looked upon as a deformity, and the power of reproduction residing in the branch is entirely lost; this is not the case with *Nymphaea*. The plant under consideration would appear, in this respect, rather to resemble such forms as *Polygonum viviparum*, *Crassula quadrifida*, *Allium vineale*, and many grasses, where the change of floral to foliar axes is accompanied by the storing of nutriment. In these cases small bulbils or fleshy plants are formed in place of flowers on the inflorescences, and the species is dependent partly or entirely upon these for its maintenance. The change in such plants is not so much to be regarded as a deformity, as a diversion of power into a different, and perhaps more economical, direction.

The distinction between these plants bearing bulbils instead of flowers and our *Nymphaea* exists principally in the persistence of the flower-stalk and sepals in the latter. The definitive change in character of the axis has set in at different stages of development in the two cases. Thus in *Crassula quadrifida*, which bears small fleshy plantlets upon its inflorescence, no part of the flower appears on these plantlets: the change occurs at, so to speak, an embryonic stage. None of

the influences tending to develope a flower have been sufficiently strong or lasting to leave a trace of their action behind them.

In *Nymphaea* the case is different. The peduncles and the sepals, as well as the swollen end of the shoot forming the receptacle, remain to bear witness to the struggle between the two kinds of branches. After the formation of a flower has apparently commenced, a complete change has occurred in the course of development; and, at the moment when the first petals should arise, a new influence supervenes; in place of petals, stamens, and carpels, normal foliage-leaves appear. This distinction is not to be lightly passed over; for the two conditions are usually regarded among teratologists as due to exactly opposite causes. Chloranthy 'differs from Heterotaxy, or substitution of leaf-bud for flower-bud, in that it occurs at a different stage. Heterotaxy is due to excess of nutrition, Chloranthy rather to injury or some debilitating cause: the discrepancies in the assigned causes for the conditions above mentioned may perhaps in great measure be attributed to the different period at which the cause in question operated[1].' While change of flower-bud to leaf-bud may be due to there being less necessity for speedy seeding, owing to abundant food, change of portions of a flower would rather point to the inability on the part of the plant to complete the formation of the expensive reproductive organs, and would suggest the production, instead of these organs, of the more immediately useful organs of assimilation.

There does not appear to be any insect or other injury to the flower in *Nymphaea*, and the close-fitting calyx and masses of hairs would render this lily quite as able to resist attack as any other variety of the species in the tanks. M. Grin, in the Revue Horticole, 1868, states that, by early excision of the carpels, it is possible to change a flower to a leafy bud; but the youngest bud I have examined shows no indications of the entrance of any insect, nor of the hypertrophy of

[1] Masters, p. 280.

tissues attendant on the presence of any foreign irritating body.

It seems necessary, therefore, having regard to the above definition, to consider the change as due to some debilitating causes. The readiness with which *Nymphaeas* are affected by alterations in the amount of light, heat, space and soil afforded them has been well shown by Caspary in his experiments on the magnificent *Nymphaea zanzibariensis*. 'If the plant be grown in a tub sixteen feet square, without covering, five or six inches under the water's surface, it is gigantic, with leaves two feet in diameter, and flowers nine inches and more across. If grown in a flat pan fifteen inches in diameter, the leaves and flowers are only half the size. While, in a pot eight inches in diameter, the flowers hardly reach an inch in diameter[1].'

The changes induced in *Nymphaea Lotus* are probably due to the introduction of the plant to our greenhouses from the sunlit lakes of Central Africa. It must be borne in mind, however, that we do not know the plant in its own home; and it is quite possible that this abnormality may be not uncommon in its native habitat.

The plant differs essentially, as we have seen, from cases where the change in the flower is of no further use. We may rather regard the present instance as analogous to that of *Opuntia*, whose fruits, when placed in the soil, grow into new plants, roots being developed from their bases, and shoots from their apices[2]. The flower is, in each case, prevented from ripening its seeds; and yet, so strong is the tendency towards reproduction residing in the branch, that, when prevented from developing in the normal manner, it is able to substitute the probably less expensive vegetative reproduction, and thus still to perform its function.

In *Nymphaea* the change is from the uncertain method of cross-fertilization and dispersal to the surer, though more primitive, method of multiplying by means of tubers dropped from the decaying peduncles into the surrounding mud. The

[1] Engl. Jahrb. iv. 116.

[2] Morris, in Gard. Chron., 22 Sept., 1888, Fig. 43.

retention of the peduncle is of evident advantage, as is that of the sepals. The receptacle, swollen under normal circumstances, is also retained, and stimulated to more active growth; and it is very probably assisted in this growth by the leaves and roots temporarily developed upon it. The formation of the tuber is, however, probably dependent on the tuberous habit of the species, just as the axillary bulbils in the inflorescences of *Allium*, and the small green tubers in the axils of the sepals of the potato, are related to the presence of these modifications in the branches of these plants.

Looking at the deformity then as a method of reproduction, the plant may be compared, on the one hand, with those which ensure the perpetuation of the species by the formation of few seeds suitably placed in the soil; thereby sacrificing the advantages of wide dispersal. On the other hand, it may be compared with those that appear voluntarily to forego the advantages of cross-fertilization.

Under the first heading may be placed *Voandzeia subterranea*, *Arachis hypogaea*, and others which bury the fertilized ovary under the ground. The second category includes those plants which ensure self-fertilization by the unopened condition of their flowers, which, in *Euryale*, frequently never reach the surface of the water[1], and a host of cleistogamous plants, where the expensive, showy organs, which usually attract insects, are, to a great extent, dispensed with, and a few fertile seeds are developed close to the soil.

[1] Caspary in Engler and Prantl, Nymphaeaceae, p. 3.

DESCRIPTION OF FIGURES IN PLATE V.

Illustrating Mr. C. A. Barber's paper on *Nymphaea Lotus, var. monstrosa.*

Fig. 1–3. Preparations of a young deformed bud of *N. Lotus v. monstrosa.*

Fig. 4–5. Preparations of an older bud.

Fig. 6. Successive leaves from the central part of a bud.

Fig. 7. A tuber which has developed leaves and roots.

Fig. 8. A portion of the same with hairs cleaned away to show the development of the roots.

Fig. 9. An old tuber with axillary buds.

Fig. 10. Tuber after all temporary leaves and roots have decayed: found in the mud.

Fig. 11. The same cleaned: showing the fence-like arrangement of the inturned petioles.

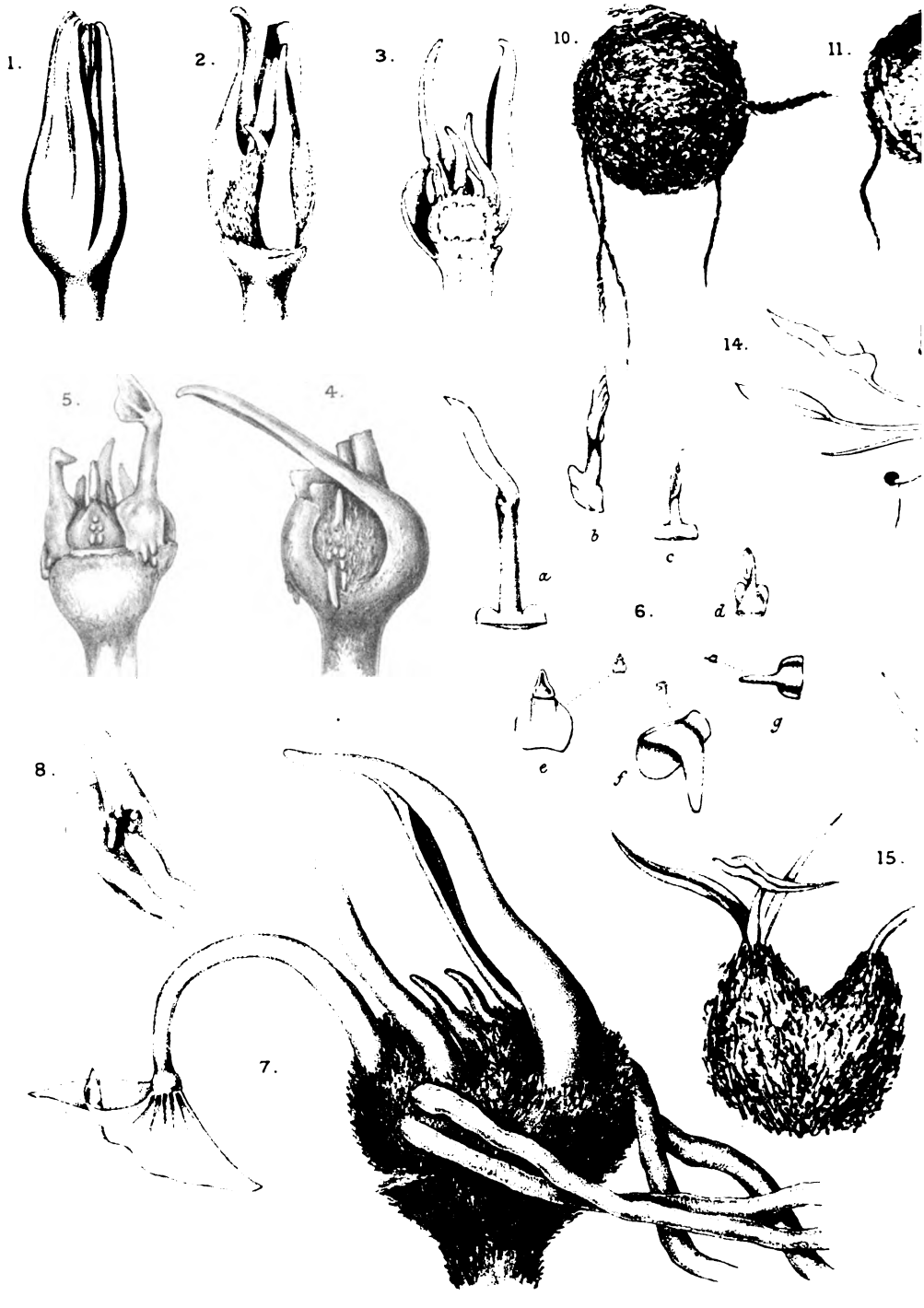
Fig. 12. The same, cut in half: showing apical bud.

Fig. 13. Germination of a similar tuber in the spring.

Figs. 13 *a*, *b*, *c*. Successive first leaves of the same specimen.

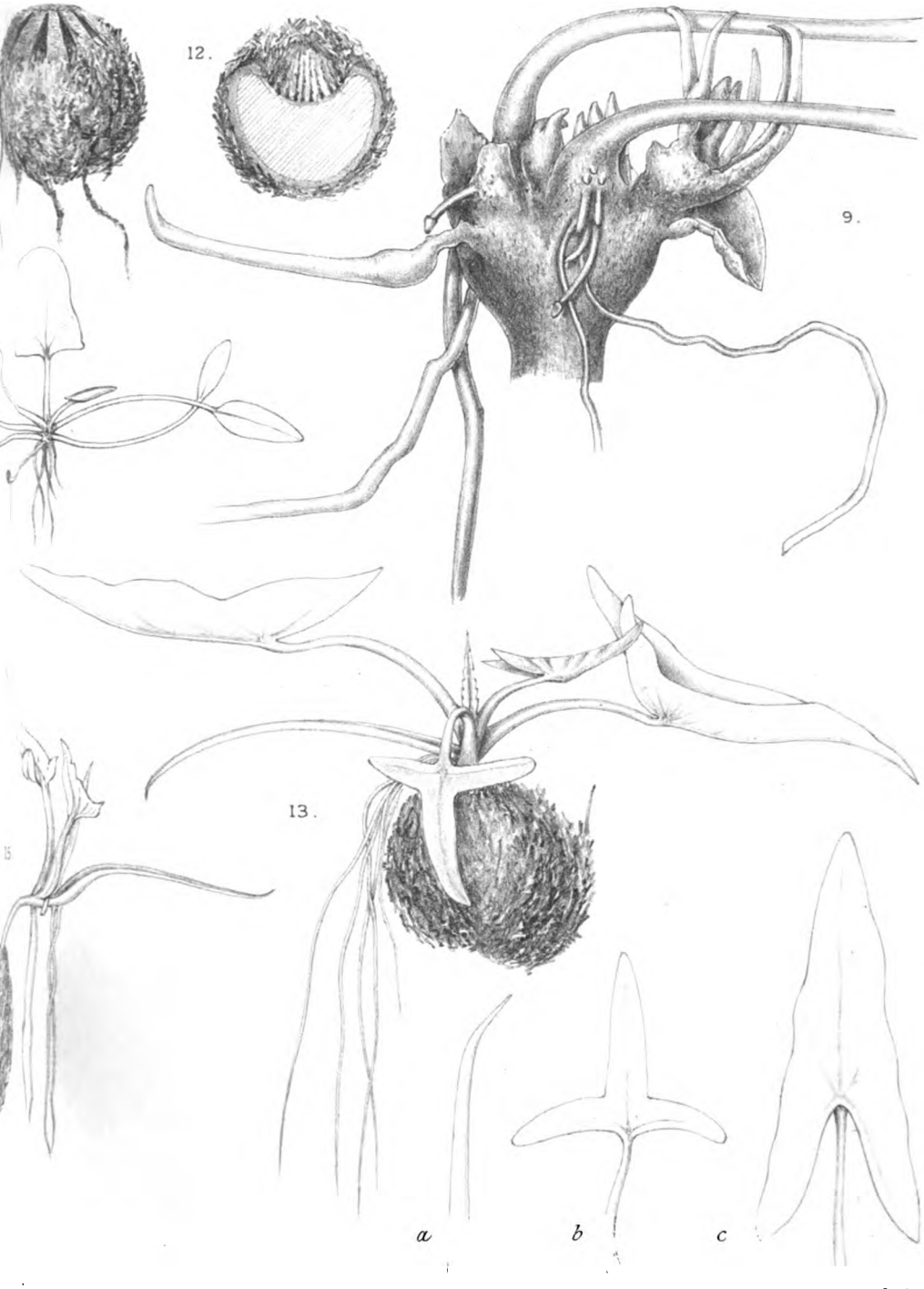
Fig. 14. Germination of the seed of *N. Lotus*.

Fig. 15. Germination of a tuber where one of the axillary buds is developing.



C.A.Barber del.

BARBER.— ON NYMPHÆA LOTUS var. MONSTROSA.



University Press, Oxford.

On the change of shape exhibited by Turgescent Pith in water[1].

BY

ANNA BATESON.

IT is well known that when turgescent pith is placed in water it increases greatly in length, but we have no accurate knowledge of any changes occurring in the transverse dimensions.

The following experiments, undertaken at the suggestion of Mr. F. Darwin, are directed to this question.

Pfeffer (Pflanzenphysiologie, ii. p. 12) points out that it is to be expected that a cell-membrane should exhibit different degrees of cohesion and of elasticity in different directions. He goes on to point out that the filaments of the Cynareæ are clearly more extensible longitudinally than tangentially. Otherwise it would be incomprehensible that the component cells should hardly change in transverse diameter whilst increasing very considerably in length. 'The cells retain their cylindrical shape, whereas if their walls were equally extensible in all directions they would assume a tub-like form from the outward bulging of their side walls. This is the case with an india-rubber tube into which water is forced while the two ends are compelled, by being fixed to glass tubes, to retain their original diameter.'

The well-known researches of De Vries[2] on the shortening of the roots of *Carum*, *Dipsacus*, etc., also bear on this subject because they demonstrate the different extensibility of the cell-wall in different directions. De Vries found that portions of these roots when placed in water become shorter and at the same

[1] A preliminary note on this subject has appeared in the Proceedings of the Cambridge Philosophical Society, vol. 6, part 6, p. 358.

[2] Landwirthschaftliche Jahrbücher, 1880.

time thicker. He gave reasons for believing that this phenomenon is essentially the same as the lengthening of ordinary pith in water, although in this latter case no narrowing in the transverse diameter was at that time known to occur. De Vries' view that 'the contraction of roots is a special form of cell-extension' is supported by the following experiments, in which as the pith becomes longer it, in many cases, diminishes[1] in transverse diameter, and thus supplies a resemblance between the two phenomena with which De Vries was not acquainted.

Method. An oblong piece of turgescent pith of about 5 mm. in thickness[2] and 10–15 mm. in length, cut from the stem of a plant, was placed on its side in a flat-bottomed vessel and the changes in thickness taking place on the addition of water were noted. The measurements were made by means of a vertical micrometer-screw graduated to ·01 mm. The screw carries a vertical needle at its lower extremity, which serves to make contact with the surface of a few drops of oil contained in a minute cup resting on the upper side of the pith. If the thickness of the pith varies, the cup of oil is necessarily raised or lowered by amounts easily read off by raising or lowering the screw until the needle-point once more dimples the surface of the oil[3].

The only difficulty connected with the method is that it is not easy to get pieces of pith symmetrically freed from external resisting tissues; unless this is carefully done the pith is liable to bend as it absorbs water. This source of error was foreseen, and all possible care was taken to overcome it.

Helianthus annuus, the Sunflower.

The pith having been placed in the flat-bottomed vessel

[1] This is not the case in all the species examined.

[2] Thickness is used in the ordinary sense of a measurement at right angles to the longitudinal axis.

[3] This method, or a modification of it, is a convenient one for many other purposes. For instance, if the oil-cup is fixed to the top of the micrometer-screw it is easy to measure the rate of growth of a plant. The string attached to the plant passes over a pulley in the usual way, and the weight bearing a needle-point makes contact with the oil-surface.

a slight diminution in thickness is generally noticed due to shrinking from loss of water by evaporation. When the water is added one of two things happens.

(1) The transverse diameter begins at once to diminish.

(2) Or the diameter at first increases and then diminishes. This dissimilarity in behaviour will be explained hereafter.

In the following tables the increase (+) and diminution (−) in the thickness of the pith are expressed in hundredths of a millimeter.

SUNFLOWER PITH, GAIN OR LOSS IN THICKNESS.

Experiment 1. August 4, 1887. Diameter not measured.		*Experiment* 2. August 4, 1887. Transverse diameter at end of experiment 5·27 mm.		*Experiment* 3. August 3, 1887. Transverse diameter at end of experiment = 5·08 mm.	
Time.		Time.		Time.	
4.5 p.m.	In air.	11.48 a.m.	In air.	11.36 a.m.	In air.
.6 „	− 0·5		water added.		0·0
	water added.	11.49 „	0·0	·37 „	− 0·5
·7 „	− 1·0	·50 „	− 2·0		water added.
·8 „	− 1·0		− 1·0	11.38.5 „	+ 0·5
·9 „	− 2·0	·51 „	− 2·5	·39 „	+ 1·0
·12 „	− 2·5	·52 „	− 2·0	·40 „	+ 3·0
·13 „	+ 0·5	·54 „	− 3·5	·41 „	+ 1·5
·16 „	− 0·5	12.0	+ 1·0	·42 „	− 1·0
		12.6 p.m.	0·0	·44 „	0·0
				·45 „	− 0·5
				·47 „	− 5·0
				·48 „	− 1·5
				·48 „	− 0·5
				·49 „	− 0·5
				·49 „	− 1·0
				·50 „	− 2·5
				·51 „	− 1·5
				·53 „	− 1·5
					− 1·0
				11.54 „	− 1·0
				·58 „	− 2·0
				·59 „	0·0
				12.2 p.m.	− 0·5
				·7 „	− 0·5
				·9 „	0·0

RESULTS:—Exp. 1. Transverse diameter diminishes by 0·065 mm.

Exp. 2. Transverse diameter diminishes by 0·10 mm. = 1·9 per cent. of the diameter measured at the end of the experiment.

Exp. 3. Transverse diameter increases by 0·06 mm. = 1·2 per cent., then diminishes by 0·205 mm. = about 4 per cent.

In Experiment 3 the pith shows the preliminary thickening mentioned above.

Sambucus nigra, the Elder.

The results are similar to those obtained with the Sunflower. The pith sometimes gets narrower at once, but usually expands before becoming narrower.

ELDER PITH. GAIN OR LOSS IN THICKNESS GIVEN IN HUNDREDTHS OF A MM.

Experiment 4. June 6, 1887. Diameter at end of experiment = 4·25 mm.		*Experiment* 5. May 24, 1887. Diameter 5·20 mm.	
Time.		Time.	
12.3 p.m.	In air.	10.40 a.m.	In air.
12.4 „	− 0·5	·42 „	− 1·0
	water added.	·43 „	0·0
·5 „	+ 0·5	·49 „	0·0
·6 „	− 0·5		water added.
·7 „	− 0·5	·50 „	0·0
·8 „	− 1·0	·52 „	+ 1·0
·10 „	− 0·5		+ 0·5
·12 „	− 1·5	·53 „	+ 0·5
14 „	− 1·0	·56 „	+ 1·0
·25 „	− 2·0	·59 „	+ 0·5
·29 „	0·0	11.5 „	− 0·5
·30 „	0·0	·16 „	0·0
1.5 „	− 1·0	·22 „	− 0·5
		·37 „	0·0
		·43 „	− 0·5
		12.10 p.m.	+ 0·5
		·23 „	0·0
		3·7 „	− 1·5

RESULTS:—Exp. 4. Transverse diameter diminishes, almost at once by 0·08 mm. = 1·9 per cent.

Exp. 5. Transverse diameter increases by 0·035 mm. = about 0·7 per cent., then diminishes by 0·025 mm. = about 0·5 per cent.

RHUBARB PITH. GAIN OR LOSS IN THICKNESS GIVEN IN HUNDREDTHS OF A MM.

Experiment 6. May 18, 1887. Diameter = 7.5 mm.		*Experiment* 7. May 17, 1887. Diameter not measured.	
Time.		Time.	
9.53 a.m.	In air.	2.15 p.m.	In air.
.56 ,,	− 2.0	.18 ,,	
.59 ,,	− 1.0	.21 ,,	− 1.
10.0 ,,	water added.	.24 ,,	0.0
.1 ,,	+ 2.0	.25 ,,	water added.
	+ 1.0	.26 ,,	+ 1.0
.2 ,,	+ 1.0	.28 ,,	0.0
.3 ,,	+ 1.0	.29 ,,	+ 2.0
.5 ,,	+ 1.0	.31 ,,	0.0
.6 ,,	0.0	.37 ,,	+ 0.5
	+ 0.5	.38 ,,	+ 0.5
.7 ,,	+ 0.5	.39 ,,	− 1.0
.8 ,,	+ 1.0	.40 ,,	+ 1.0
.9 ,,	0.0	.41 ,,	0.0
.12 ,,	+ 1.0	.49 ,,	0.0
.13 ,,	0.0	.51 ,,	+ 1.0
.21 ,,	0.0	3.1 ,,	0.0
.39 ,,	− 1.0	.4 ,,	+ 1.0
.40 ,,	0.0	.9 ,,	0.0
.50 ,,	− 1.0	.12 ,,	− 1.0
	+ 1.0	3.17 ,,	− 1.0
11.3 ,,	− 1.0	.20 ,,	0.0
11.20 ,,	0.0		− 0.5
.24 ,,	0.0	.39 ,,	− 0.5
.31 ,,	− 0.5	.50 ,,	− 0.5
.42 ,,	0.0	4.2 ,,	− 0.5
12.29 p.m.	− 0.5	.11 ,,	− 1.0
1.0 ,,	0.0	.36 ,,	− 1.0
2.13 ,,	− 2.0	.38 ,,	0.0
.50 ,,	0.0	.51 ,,	− 1.0
3.4 ,,	− 0.5	5.5 ,,	− 1.0
		.12 ,,	0.0
		.18 ,,	− 0.5
		.25 ,,	− 0.5
		.32 ,,	.0
		May 18.	
		9.28 a.m.	− 20.0

RESULTS:—Exp. 6. Transverse diameter increases by 0.09 mm. = about 1 per cent., then diminishes by 0.055 mm. = about 0.7 per cent.

Exp. 7. Transverse diameter increases by 0.06 mm., then diminishes by 0.29 mm.

Impatiens Sultani.

This plant gave different results from those above detailed. Its pith continued to expand transversely in water without afterwards becoming narrower. Nine pieces of pith were measured and none of these showed the final contraction characteristic of Elder and Sunflower and Rhubarb. One of these cubes behaved abnormally in contracting during the first half-hour it was in water, after which it expanded: all the other eight cubes expanded steadily during the whole time they were in water [1].

Two examples follow:—

IMPATIENS SULTANI PITH. GAIN OR LOSS IN THICKNESS GIVEN IN HUNDREDTHS OF A MM.

Experiment 8. June 2, 1887. Diameter = 4·81 mm.		*Experiment* 9. May 31, 1887. Diameter = 7 mm.	
Time.	In air.	Time.	In air.
12.21 p.m.	water added.	10.16 a.m.	− 2·0
.22 „	+ 1·0	.17 „	− 1·0
.31 „	+ 0·5	.20 „	− 0·5
.33 „	+ 0·5	.21 „	water added.
.36 „	0·0	.22 „	+ 0·5
.37 „	+ 1·0	.23 „	+ 1·0
.42 „	+ 1·0	.24 „	+ 1·0
2.50 „	+ 8·0	.25 „	+ 0·5
3.29 „	0·0	.26 „	+ 0·5
4.10 „	+ 0·5	.53 „	+ 8·0
		11.3 „	+ 2·0
		.10 „	0·0
		.35 „	+ 2·0
		12.28 p.m.	+ 2·0
		2.29 „	+ 1·0

RESULTS:—Exp. 8. Transverse diameter increases by 0·125 mm. = about 2·6 per cent.

Exp. 9. Transverse diameter increases by 0·185 mm. = about 2·6 per cent.

[1] The cells which make up the pith are remarkable in having their transverse greater than their longitudinal diameter.

The following list gives a summary of the general results of the experiments, including some which are not given in detail.

SUNFLOWER.	RHUBARB.
Transverse diameter of the pith diminishes at once without previous increase	Increases, then diminishes.
Ditto.	Ditto.
Ditto.	Ditto.
Ditto.	Ditto.
Ditto.	
Increases, then diminishes.	
Ditto.	

ELDER.	IMPATIENS SULTANI.
Diminishes at once.	Increases, no subsequent diminution.
Ditto.	Ditto.
Ditto.	Ditto.
Increases, then diminishes.	Ditto.
	Ditto.
	Ditto.
	Ditto.
	Ditto.
	Diminishes, then increases.

General Results. The cases above considered fall into classes—

(1) Sunflower, Elder, Rhubarb, in which transverse contraction is the final result.

(2) *Impatiens Sultani*, in which no such contraction occurs.

What occurs under Class (1) must be this. Where the pith is placed in water it begins to expand in all directions, but the longitudinal extensibility of the cell-walls being much greater than their transverse extensibility, an increase in length continues long after transverse expansion has ceased, and therefore the pith is forced to return towards its original transverse dimensions, and becomes narrower. Where, as in the case of the Sunflower and Elder, the contraction frequently begins at once, it is clear that the difference between the longitudinal and tangential extensibility is so great, that the tendency to transverse expansion is from the first obliterated

In the case of *Impatiens Sultani* the transverse extensibility is so great that transverse expansion is not only clearly apparent from the first, but is never overcome by the longitudinal expansion—the pith continues to expand transversely and never exhibits a subsequent contraction.

If the transverse extensibility of the cell-walls in *Impatiens* is so great relatively to the longitudinal extensibility, we should expect to find the longitudinal extensibility in *Impatiens* small in comparison with what it is in the Sunflower and Elder.

The following figures show that this is the case.

Longitudinal Expansion of Pith when placed in water, given in per-centages of the original length.

SUNFLOWER	(1)	14·3	p. c. after	2 hrs.	38 min.	immersion.
	(2)	15·9	„	5 „	50	„
ELDER	(1)	9·5	„	1 „	50	„
	(2)	16·9	„	2 „	0	„
	(3)	16·8	„	2 „	14	„
IMPATIENS	(1)	4·0	„	1 „	30	„
	(2)	4·4	„	2 „	16	„
	(3)	5·9	„	3 „	6	„
	(4)	3·1	„	4 „	23	„

If we express the relation between longitudinal and transverse extensibility by the fraction $\frac{L}{T}$, we can place the tissues with which we are acquainted in the following order.

(1) The highest value of $\frac{L}{T}$ occurs in those cases (e.g. in experiments 1, 2, 4 under Elder and Sunflower) where no preliminary expansion occurs.

(2) $\frac{L}{T}$ is of lower value in the case of Rhubarb where a preliminary expansion always occurs.

(3) $\frac{L}{T}$ of still lower value in *Impatiens Sultani* where no transverse contraction takes place.

(4) $\frac{L}{T}$ of lowest value where, as in roots, T is greater than L, and produces a longitudinal contraction.

It is probable that by the study of other tissues, especially those of roots, the series between the Sunflower pith and the contracting root-tissues of De Vries' experiments might be made even more complete. But enough has been done to fully confirm that naturalist's view of the question.

BOTANIC GARDEN LABORATORY, CAMBRIDGE.

Observations on the Structure of the Nuclei in Peronospora parasitica, and on their behaviour during the formation of the Oospore.

BY

HAROLD W. T. WAGER,

Assistant Lecturer and Demonstrator in Biology in the Yorkshire College.

With Plate VI.

IT has long been known that in many of the fungi the reproductive organs, asci, basidia, spores, etc., contain nuclei; the presence of these bodies in the mycelium has also been more or less satisfactorily demonstrated in many cases. Schmitz[1] states that, by means of haematoxylin, he has been able to show that the cells of all fungi, not including the Schizomycetes, contain one or more nuclei. He bases his assertions upon the fact that these bodies become more deeply stained than the remainder of the protoplasm. This method of determining the presence of nuclei is, however, hardly satisfactory, as in some cases the supposed nuclear bodies are so small as to be scarcely distinguishable from the ordinary granules in the protoplasm; moreover, it sometimes happens that, owing to defective methods of preparation, the protoplasm forms roundish, deeply staining coagulations, which may be easily mistaken for nuclei. De Bary[2], in discussing this question,

[1] Sitzgsber. d. Niederrh. Ges. 1879.

[2] Morphology and Biology of the Fungi, &c., English edition, 1887.

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says:—'The objects under consideration, except in the Saprolegnieae, are of such minute size, that the satisfactory discrimination of true nuclei from other small bodies contained in the protoplasm, and like them perhaps rendered more distinct by colouring reagents, is extremely difficult, and can only be obtained after renewed investigation.'

There is, as is well known, no decisive test for nuclei except the morphological one of structure. Zacharias[1] and others have, it is true, done much to show that the presence of a nucleus or nuclear substance may be determined by chemical means; but their results, although they are extremely valuable, are not sufficiently satisfactory or definite to be of much use in determining whether the minute deeply staining bodies present in the protoplasm of many of the lower plants can be looked upon as nuclei or not. It is therefore necessary, in order to decide whether in any given case the numerous small bodies in the protoplasm should be looked upon as nuclei—in the same sense in which we speak of them in the higher plants and animals—to show that they have some perfectly definite structure which distinguishes them from the other bodies in the protoplasm. This has been shown to be the case in certain of the fungi. In the Saprolegnieae, for example, the resting nuclei have a structure which is distinctly comparable with the structure of the nuclei in the higher plants, and in some other fungi a perfectly characteristic structure has also been found to exist.

Perhaps the most important factor in the determination of this question lies in the division of the nucleus; where this is indirect or karyokinetic we have the most satisfactory proof of the nuclear nature of the body in question. It is not necessary that the changes which take place during this karyokinesis should be so complicated or so numerous as those which take place in the higher plants. It is sufficient if we are able to recognise that the division is one which conforms to some simple generalisation in which the changes

[1] Bot. Zeitung, xlv, 1887.

which take place in the nuclei of the higher plants are included. It is a recognised feature of all karyokinesis that the deeply-staining substance—chromatin—is capable of becoming re-arranged in such a manner as to allow of an equal or in some cases perhaps even an unequal division of it into two parts, each of which becomes a perfect nucleus. The simplest expression of these changes in the division of ordinary nuclei is given by Boveri[1], who states that it consists in 'the collection of the chromatic nuclear material in a (definite) number of isolated parts, of characteristic form, varying with the kind of cell—the chromatic elements; the formation of an achromatic figure of threads either from the nucleus or from the cell-substance, with two poles; the arrangement of the chromatic elements so far as their number, size, and form allow, in the equatorial plane of the achromatic figure; the division of the chromatic elements into two halves of which one half goes to either pole; the transformation of the daughter elements into the network of two new nuclei.' The 'chromatic elements' are now known to consist only in part of chromatic substance.

So far as I am aware two observers only have made researches upon karyokinesis in the nuclei of the fungi. Rosenvinge[2] has obtained indications of karyokinesis in the basidia of certain Agaricineae, but was not able to demonstrate it satisfactorily; and Hartog[3] has recently shown that some phenomena of karyokinesis occur in the division of the nuclei in the Saprolegnieae. The object of this paper is to show that the nuclei in the cells of *Peronospora parasitica* have a definite structure; and that the process of division is a karyokinetic one closely allied to that which takes place in the nuclei of the higher plants; and also that the nucleus plays an important part in the formation of the oospore.

[1] See Waldeyer, Ueber Karyokinese und ihre Beziehungen zu den Befruchtungsvorgängen. Archiv f. Mikr. Anat. 1888. See also the translation by Dr. Benham in Q. J. M. S., July 1889.

[2] Ann. des Sci. Nat., série vii, tome iii.

[3] Recherches sur la structure des Saprolegniées.

This work was begun in October 1887, in the botanical laboratory of the Normal School of Science, at the suggestion of Dr. Scott. My first work was done on *Cystopus candidus* and *Pythium*, and was undertaken to confirm Fisch's results as to fertilisation, etc. Some important facts were obtained which tended to show that Fisch's results were in part erroneous; but owing to the lack of material the work was postponed until the following autumn, when I obtained a mass of fresh material, which was, however, found to consist almost entirely of *Peronospora parasitica*, and as this was in excellent condition I was induced to work out the details of nuclear structure on it, in addition to my work on *C. candidus* and *Pythium*, which is not yet completed.

Peronospora parasitica is very abundant on certain cruciferous plants; it is very common on the Shepherd's Purse, *Capsella bursa-pastoris*, where it exists, together with *Cystopus candidus*, in the form of white patches covering the stem, leaves, and fruits; its hyphae ramify in all directions through the tissues of the host-plant, sending out numerous haustoria, which penetrate the cells, and in many cases completely fill them. The haustoria are globular, or short, thick, club-shaped expansions, connected to the hyphae by narrow basal portions, at the point where they perforate the cell-wall[1]. Large numbers of much branched gonidiophores project through the epidermis of the host plant. The tips of the branches are bifid. The gonidia are large and globose, and are borne singly at the apices of the branches. Sexual organs, antheridia, and oogonia are found in large numbers between the cells of the host-plant.

All parts of the fungus contain numerous nuclei. They occur in the mycelium, in the antheridia and oogonia, and in the gonidia or zoosporangia. To obtain preparations showing the nuclei, thin sections of the infected plant were cut and stained for some time in a dilute solution of haematoxylin, and mounted in Canada balsam. Other sections were stained in picronigrosin,

[1] Cf. De Bary, Recherches sur le développement de quelques Champignons parasites, Ann. des Sci. Nat., 1863.

and mounted in glycerine jelly. None of these preparations, however, were found to exhibit the structure of the nucleus satisfactorily, as the protoplasm itself was stained too deeply, and sections could not be obtained thin enough to allow the nucleus to be distinctly seen.

The most successful preparations have been made by means of a Cambridge ribbon-section-cutting microtome. It may be useful here to give a few details as to the method employed. The fresh infected tissues of the Shepherd's Purse were cut up into small pieces, and placed at once either in absolute alcohol or chromic acid solution. They were kept here until thoroughly penetrated, and were then prepared for embedding in paraffin wax. The method of preparation differs slightly from that required for animal tissues. The chromic acid specimens were thoroughly washed in 70 per cent. of alcohol, then transferred to methylated alcohol, and finally to absolute alcohol. Tissues prepared in absolute alcohol do not, of course, require these intermediate washings. The pieces of tissue may then be stained *en bloc*, or the separate sections may be stained, when cut, on the slide. The latter method was found to be preferable.

For staining *en bloc* the pieces of tissue were transferred to the staining fluid, a strong solution of haematoxylin in Kleinenberg's solution. They were left in this for a few days, and were then successively washed in 70 per cent., 90 per cent., and 100 per cent. alcohol. They were left in the absolute alcohol for twenty-four hours. The tissues should be thoroughly dehydrated, otherwise the greatest difficulty will be found in embedding them satisfactorily. After being thoroughly dehydrated in alcohol, they were transferred to turpentine for about forty-eight hours, and were then placed in soft melted paraffin wax for about twenty-four hours, and were finally transferred into hard melted paraffin wax for about two days. I have constantly used a wax melting at 59° C. The softer wax should have a melting-point of about 49° to 50° C. The pieces of tissue were then embedded in small square blocks of paraffin, and very thin sections cut by

means of the microtome. These were mounted at once in Canada balsam.

The best preparations were made however by staining the sections, when cut, on the slide. The method of preparation was the same as in the above case, except the staining *en bloc*, which was left out. The sections were cemented to the slide with a solution of white of egg and glycerine. The paraffin wax was then melted by heating the slide on a water bath, and washed off in turpentine. The slide was next placed in absolute alcohol, and was afterwards transferred to the staining solution. The best staining solution was found to be a dilute solution of Kleinenberg's haematoxylin in water. This was made by adding a few drops of the strong haematoxylin-solution to a beaker of water until the whole was decidedly coloured. The sections were left in this until they were considerably overstained, and were then placed in a dilute solution of acid alcohol for a short time to reduce the stain. The acid alcohol solution was only just strong enough to reduce the stain slowly. It was made by adding a few drops of strong hydrochloric acid to a beaker of 70 per cent. alcohol. The sections were then washed successively in 70 per cent., 90 per cent., and 100 per cent. alcohol, and were next transferred to turpentine until quite clear and transparent (a few minutes were found to be sufficient for this), and were finally mounted in Canada balsam. The preparations thus obtained, owing to the thinness of the sections, which were in many cases only about the $\frac{1}{8000}$ of an inch in thickness, exhibited the structure of the nucleus clearly and distinctly.

It was found to be quite possible to distinguish the nuclei without the use of staining reagents, especially in sections of alcoholic material when mounted in glycerine. The nuclei presented the appearance of bright refractive bodies, which could be easily distinguished from the surrounding granules. It may be pointed out here that Zalewski[1] describes the nuclei in the oospore of the allied genus *Cystopus*, in the

[1] Bot. Centrbl. xv, 1883.

fresh state, as highly refractive bodies, which may be vacuoles or accumulations of hyaline protoplasm.

The observations which follow, upon the nuclei in the various organs of the fungus, have been made almost entirely upon sections obtained by means of the ribbon-section-cutting microtome, and stained with haematoxylin.

The Nuclei of the Hyphae.

The hyphae are much-branched tubes which ramify in all directions between the cells of the various tissues of the host plant. They contain a considerable quantity of protoplasm, which forms a thick parietal layer on the walls of the hyphae, enclosing a central cavity, across which numerous thick protoplasmic strands pass. In certain places, however, the hyphae appear to be full of protoplasm, and it is probable that at these points rapid growth or elongation is taking place. Nuclei are found in large numbers in the protoplasm in all parts of the mycelium, both in the parietal layer and in the protoplasmic strands, but in those places, mentioned above, where the hyphae appear to be completely full of protoplasm, the number of nuclei present is considerably increased, and they form a not inconsiderable portion of the contents of the hyphae. In other places, however, the nuclei are comparatively few in number, and are scattered here and there, often at considerable intervals, in the protoplasm.

The nuclei, in the resting stage, are spherical or slightly oval bodies. In those parts of the hyphae which appear to be rapidly growing the nuclei may become considerably elongated and deformed. Each nucleus is vesicular, and contains a considerable quantity of chromatin, which is arranged peripherally on its wall (Fig. 1, 1). In some nuclei the chromatin appears to form a continuous ring, while in others it is broken at one or more points, and in others again it presents a somewhat granular appearance. It is therefore probable that the chromatin-body is of a somewhat irregular shape, and may form a coarse network of very thick threads ; or it may be divided

into two or more segments. But although indications of the above structure are visible, it is impossible to say with certainty what is the exact structure of the chromatin body in the nucleus in the resting stage. Inside the chromatin is a mass of nucleoplasm which does not stain very deeply, and in many cases is not distinctly seen owing to the thickness of the surrounding chromatin. There is, so far as I am able to determine, no nucleolus present. The nucleus is surrounded by a limiting layer or nuclear membrane, which can however be seen better at a later stage. Rosenvinge[1] has obtained nuclei in certain fungi which have a somewhat similar structure to the above, but in which no indications of a separation of the chromatin into distinct parts was observed. Nuclei which have been too deeply stained appear in many cases to be perfectly homogeneous. The division of the nucleus in the mycelium is indirect, but in badly stained sections, or when seen under insufficient magnifying power, the phenomena of karyokinesis cannot be observed. In such cases the division of the nucleus appears to be direct; it first elongates, then becomes constricted, or dumb-bell shaped, then the connecting portion between the two knobs becomes thinner and thinner until it finally breaks across, and the two daughter nuclei are formed. Karyokinesis when well seen includes all these phenomena, but in addition the breaking up and rearrangement of the chromatin can be seen, when the nucleus is well stained, and a sufficiently high magnifying power used.

The division of the nucleus is preceded by a perceptible increase in size and by considerable changes in the chromatin, leading to the formation, or separation of it, into distinct threads (Fig. 1, 2, 3). In many cases the chromatin appears to form granules in the nucleus, but their appearance seems to be due to the fact that the nucleus is in such a position as to show only the ends of the threads. The threads appear to be few in number; they are somewhat elongated, and are arranged irregularly. The nuclear membrane can be distinctly seen at

[1] Loc. cit.

this stage; it appears to belong entirely to the nucleus, and it persists, so far as can be seen at present, during the whole of the changes which the nucleus undergoes during its division. The nucleus next elongates slightly, and at the same time the threads arrange themselves longitudinally in the equatorial plane. A separation of the threads then takes place into two groups which travel to either end of the nucleus (Fig. 1, 4, 5). At this stage the nucleus appears to consist of an oval mass of slightly staining substance, in which the deeply stained threads are to be seen grouped at each end; this mass probably consists of the nuclear membrane enclosing the nucleoplasm. The next stage is seen in the gradual constriction or inflection of the nuclear membrane (Fig. 1, 6); and at the same time the filaments at each end of the nucleus begin to unite with each other to form the daughter nuclei. A narrow bridge connecting the two nuclei remains for some time, but this is finally broken down, and the two daughter nuclei are completely formed.

I have not been able to observe the formation of a spindle-figure, nor the longitudinal splitting of the chromatic elements.

The Nuclei of the Oogonium.

The oogonia (Fig. 4, etc.) are formed as terminal or intercalary swellings of the hyphae. Large quantities of protoplasm and numerous nuclei pass into them from the hyphae, and when they have reached their full size they are cut off from the thallus by one, or if their position is intercalary, by two transverse walls. About the same time that the oogonia are cut off, one or more antheridia are developed close to each oogonium (Figs. 4 and 5, *a*), either from the hypha in connection with it or from hyphae adjacent. The antheridia also contain protoplasm and nuclei derived from the hyphae, and like the oogonia are cut off from the thallus by transverse walls. The oogonia and antheridia are found in large numbers in all parts in the host-plant. They appear to be developed at first near the surface, but are afterwards

produced abundantly in the deeper tissues of the plant. They sometimes vary considerably in size, but as a rule the oogonia obtained in sections from the same piece of infected tissue do not exhibit much variation in this respect.

The number of nuclei present in a single, young oogonium is considerable. I have counted as many as 112; and it is possible that in some oogonia there are more than this; while in others the number is considerably less. The antheridia contain from six to twelve nuclei. It is almost, if not quite, impossible to count the nuclei in an oogonium in a section cut by hand. The protoplasm of the oogonium is too dense and stains too deeply to allow all the nuclei to be seen, and it is impossible to obtain successive sections of an oogonium when cut by hand. In sections cut by the ribbon-microtome, however, these objections are not met with, and in a good series of sections we are able to obtain several successive sections of one oogonium, in each of which the nuclei can be easily seen and counted. The total number of nuclei present in a single oogonium can then be obtained by taking the sum of the nuclei found in all the sections of it.

The structure of the nuclei in the oogonium, at the time when the latter is delimited from the thallus, is similar to the structure of the resting nuclei in the mycelium. This simple structure is not retained long. During the formation of the oosphere the nuclei undergo changes which lead to their division; the process of formation of the oosphere being a more complicated one than is generally supposed, at least so far as *Peronospora parasitica* is concerned. The prevalent ideas concerning the formation of the oosphere are somewhat as follows. The oosphere begins to be formed soon after the delimitation of the oogonium from the thallus by a slowly progressing separation of the protoplasm into a central denser portion which forms the oosphere, a smooth globular body surrounded by a delicate hyaline membrane; and an outer portion, the periplasm, which surrounds the oosphere and takes part in the formation of the exosporium. Further changes, possibly connected with an act of fertilisation, then

take place leading to the formation and ripening of the oospore.

This description may perhaps be looked upon as a simple expression of the phenomena in question. It does not, however, represent what in reality takes place. The formation of the oosphere is preceded by changes which take place in the nuclei both of the oogonium and antheridium. They become much enlarged, and, at the same time, the chromatin becomes distinctly visible in the form of threads, and in some cases a loop-like structure (Fig. 2, 1) of the threads can be observed. At the same time changes take place in the protoplasm. Numerous vacuoles appear in it (Fig. 6, *v*); and these become much larger, so that at a later stage nearly the whole of the central space is taken up by them (Fig. 7). The protoplasm thus becomes almost entirely restricted to the periphery of the oogonium, a small quantity only of granular protoplasm remaining in the centre connected with the peripheral portion by a few thick strands. The nuclei also pass over to the periphery, the last few passing along the protoplasmic strands. The nuclei at this stage exhibit a very distinct nuclear membrane and present an appearance very much like that of the 'dense skein' stage in the higher plants. The nuclei take up a position in the protoplasm so as to form a very regularly arranged layer, on the innermost side of it, next to the central space (Fig. 8). The nuclei enlarge still more and become slightly elongated in a tangential direction. The chromatin threads become more distinct and of approximately the same size (Fig. 2, 2). They are scattered irregularly in the substance of the nucleus, which may now be described as in the 'loose skein' stage. The nuclear membrane now becomes invisible and the chromatic threads appear to lie loosely in the protoplasm. The chromatic threads next become arranged longitudinally in the equatorial plane of the nucleus (Fig. 2, 4). In some nuclei a slightly stained, somewhat cone-shaped mass may be observed at each end of the nucleus (see Fig. 9, *s*). This may be a spindle-figure, but it is much too indistinct to be

satisfactory. I have only seen it under the most careful illumination with an apochromatic objective. It is indicated in Fig. 9, but is a little too strongly shaded.

The nuclei next divide into two groups of threads which separate from each other to form two daughter nuclei (Fig. 2, 5).

Simultaneously with these changes in the nuclei of the oogonium, similar changes have been taking place in the antheridium, the nuclei of which divide up in exactly the same manner and at the same time (Fig. 8, *a*). The changes in the oogonium and antheridium go on very regularly together, but I have not been able to observe a distinct separation of the protoplasm of the antheridium into gonoplasm and periplasm at this stage.

The arrangement of the nuclei in the oogonium now becomes somewhat irregular. Further divisions of the nuclei take place; the nuclei at each division becoming smaller (Figs. 10 and 11). A small number of these then pass along the protoplasmic strands towards the centre of the oogonium (Figs. 10 and 11, *n*). It would be very interesting to find that one portion of each of the original nuclei passed to the centre in this manner, but, although I have spent a considerable time on this one point, I have never been able to observe more than three nuclei in such a position; I am, moreover, somewhat doubtful about the third nucleus, and can only assert positively that two nuclei pass towards the centre.

While these two nuclei are passing along the protoplasmic strands towards the centre, the cell-wall of the oosphere begins to form as a delicate, slightly granular layer, separating the small quantity of protoplasm in the centre with its two nuclei from the denser and more copious periplasm with its numerous nuclei outside (Figs. 11 and 12, *o*). The wall of the oosphere is undoubtedly formed from the periplasm, the nuclei presumably taking a large share in the work. The function of the periplasmic nuclei is thus seen to be a very distinct one. They divide up rapidly, so far as can be seen,

by a process of karyokinesis, into a large number of very small nuclei, and some of these are probably used up in the formation of the inner wall of the oosphere.

At about the time that the nuclei are arranged regularly in the peripheral protoplasm of the oogonium the antheridium begins to develop a fertilising tube which penetrates the oogonium, and increases in length until it comes in contact with the oosphere just at the time when the cell-wall of the latter is formed (Figs. 9 and 13, *a'*). The antheridial tube is much elongated, and does not pass directly to the oosphere, but takes a somewhat oblique course to one side of it. The end of the tube is swollen in a characteristic manner (Figs. 14 and 15, *a'*). The swelling is cylindrical and takes up about one-third of the length of the tube. It is this portion of the tube which comes into close contact with the oosphere. In two cases, at least, I have been able to observe an opening between the terminal portion of this swelling and the oosphere, (Fig. 15, *f*); this opening, however, is extremely small and easily overlooked.

The antheridium contains at this period a large number of small nuclei which have been derived from the division of the pre-existing larger nuclei. One or more of these nuclei pass over into the antheridial tube (Figs. 13 and 14, *n*), together with a small quantity of protoplasm. The oosphere at this stage contains one nucleus which exists in place of the two pre-existing nuclei, these having probably fused together to form the single central nucleus; at a later stage two nuclei are to be observed, and at a still later stage a single nucleus only is again seen. The most natural interpretation of this is, that a nucleus passes over from the antheridial tube into the oosphere, and finally fuses with the central nucleus. I have not been able to observe these phenomena directly however, and therefore I think the question as to whether fertilisation does or does not take place is at present an open one. I may mention here that Zalewski[1] has already pointed out that in *Peronospora* one nuclear body only is present at a late stage.

[1] Loc. cit.

The nuclei in the oosphere, at all stages except the earliest, appear to contain very little chromatin, and are very different in appearance from the other nuclei. I may, however, point out here that observations on the protoplasm and nuclei inside the wall of the fully formed oosphere are rendered somewhat difficult on account of the thickness of its cell-wall, which prevents the proper penetration of the preservative and other fluids. To this cause may perhaps be traced the apparent absence of chromatin in the nuclei.

At a late stage in the formation of the oosphere the antheridium contains only a very small number of nuclei. It appears that some of them pass over into the antheridial tube, and then into the periplasm, through the breaking down of the swollen end of the tube, which disappears at a later stage, the smaller portion of the tube also becoming lost to view.

The outer layer of the wall of the oospore is formed by the deposition of the whole remaining mass of protoplasm and nuclei upon the inner wall in the form of a rugose mass which gradually becomes converted into a dense exosporium. The wall of the oogonium at the same time contracts and forms at this stage a much crumpled envelope for the oospore. The antheridium, which contains a few nuclei, also appears to contract and finally disappears altogether.

I should like to call attention here to the observations made by Fisch[1] and Chmielewsky[2] on the two genera allied to *Peronospora*—*Pythium* and *Cystopus*.

Fisch states that in *Pythium* the mycelium contains large numbers of nuclei, each having a very large nucleolus. The young oogonia contain usually from ten to twenty nuclei. At the time when the oosphere is being formed, they collect together and coalesce into the single large nucleus of the ovum. The antheridial cell was found to contain only a single nucleus, but this was probably formed by the coalescence of

[1] Versamml. deutsch. Naturf. 1885. See Bot. Centrbl., 1885, p. 221.

[2] Arbeiten d. neurussischen Naturf. Ges., xiii, 1888. See Bot. Centrbl., 1889, No. 24.

several. This nucleus passes with the protoplasm into the oosphere and coalesces with the nucleus of the ovum.

He also states that *Cystopus* appears to agree with the above.

I have examined *Cystopus* myself, and am inclined to think that it agrees more nearly with *Peronospora*; on the other hand, if Fisch's observations are correct, it will be seen that the process of oosphere-formation in *Pythium* and *Cystopus* is extremely unlike that which occurs in *Peronospora*.

Chmielewsky's observations on *Cystopus* are directly contrary to those of Fisch. He accepts Fisch's statement for *Pythium*, but says that his observations on *Cystopus* are questionable. He states that the protoplasm of the young oogonia has a net-like structure, and the knots of the net, which consist of granular plasmatic aggregations, are strongly stained, and these are what Fisch must have taken for nuclei. He further states that the young oogonium in reality contains only one parietal nucleus. This is of considerable size and has the form of an ellipse, in one of the foci of which a very small nucleolus usually lies. The nucleus is very poor in chromatin.

His observations on the antheridium show that it likewise contains only one nucleus in its net-like protoplasm. It has equal size and capacity for staining with the nucleus of the oosphere. The author calls special attention to this. After the passage of the gonoplasm, which takes place through a fertilising tube which often penetrates deeply into the oosphere, two nuclei were seen which gradually approached nearer to each other. The state of fusion was seen. The ripe oospores contain always only one nucleus.

These observations seem to me to be totally different from those which I have been able to make upon *Cystopus*. I quite agree with Fisch as to the nuclei present in the oogonium, except that I think there are more than he represents. I have been able to show that the antheridium contains numerous nuclei at a certain stage in its development. The antheridial tube, in several cases which I have been able to observe, does

not penetrate deeply into the oosphere, although it appears to do so, but takes an oblique course to one side, as is the case in *Peronospora*. Lastly, I have noticed that the ripe oospore contains numerous nuclei, and this appears to agree with Zalewski's[1] observations. I propose to thoroughly investigate this question as to the formation of the oospore, fertilisation, and structure of the nucleus in *Cystopus* during the coming winter.

The Nuclei of the Gonidia.

The gonidia or zoosporangia, as before mentioned, are borne at the tips of branches of much-branched gonidiophores. They contain a very dense protoplasm, and numerous nuclei (Fig. 19). The nuclei are slightly larger than those which occur in the mycelium, and have a different structure. They are spherical or slightly oval bodies, with a very distinct outline. Each nucleus contains a small central mass of chromatin, surrounded by a less deeply staining nucleoplasm. I have not been able to observe any division in these nuclei, and I have not been able to determine whence they are derived, whether from the mycelium or from the division of a single original nucleus or nuclei in the sporangium.

In conclusion, I have to thank Dr. D. H. Scott for suggesting the work which led to this investigation; and I wish here also to thank him very heartily for his great kindness while the work was in progress. A part of it was done in Dr. Scott's laboratory at the Royal School of Mines, and a considerable portion was done in the biological laboratory at the Yorkshire College, but it was chiefly owing to the facilities afforded me in July of 1889 by Dr. Scott, at South Kensington, where he placed a set of apochromatic lenses at my disposal, that I was enabled to complete the work satisfactorily.

Summary.

The various organs of *Peronospora parasitica*, the mycelium, antheridia, oogonia, and gonidia, contain numerous deeply-

[1] Loc. cit.

staining nuclei, which in very thin sections, obtained by means of a ribbon-section-cutting microtome, and stained in a very dilute solution of Kleinenberg's haematoxylin, exhibit a very distinct nuclear structure.

The division of the nucleus takes place by a process of karyokinesis, comparable to that which takes place in the division of the nucleus in the higher plants. This can be most satisfactorily observed in the nuclei of the oogonia.

The nuclei of the oogonium at an early stage in the development of the latter are spherical or slightly oval, vesicular bodies, each of which contains a large mass of chromatin, forming a peripheral layer on its wall.

All the nuclei of the oogonium divide, and the process of division is accompanied by changes in the protoplasm, leading to the formation of the oosphere. These changes are more complicated than is generally supposed.

The protoplasm of the oogonium at an early stage appears to be a homogeneous, granular mass, containing numerous nuclei, as described above.

Numerous vacuoles appear in the centre of the oogonium, causing the greater part of the protoplasm and all the nuclei to be restricted to the periphery. At the same time the nuclei swell up, and exhibit a thread-like structure. They become arranged very regularly, and form a single layer in the parietal protoplasm.

The chromatic threads next arrange themselves in the equatorial plane of the nucleus, and then divide into two groups of threads, each of which forms a daughter nucleus.

The daughter nuclei again divide, and then two or perhaps more pass towards the centre of the oogonium, and soon afterwards the cell-wall of the oosphere begins to form on the inner side of the parietal layer of protoplasm, leaving this, together with the remainder of the nuclei outside, to form the periplasm.

From this mass of protoplasm and nuclei both the endosporium and the exosporium are formed. One or more antheridia are developed in connection with the oogonium.

The antheridia send out fertilising tubes, swollen at the ends, which pass to one side of the oosphere, come into close contact with it, and appear to open into it by a small aperture. The passage of a nucleus from the antheridium into the oosphere has not been directly observed, but it is probable that fertilisation does take place, as two nuclei have been seen in the oosphere at about the time when a nucleus or nuclei from the antheridium appear to pass over the fertilising tube.

The nuclei of the mycelium divide in a similar manner to those in the oogonium, but they do not become so large nor exhibit the details so clearly.

The gonidia or zoosporangia contain numerous nuclei, differing in structure from the nuclei in the other parts of the fungus. They consist of a central mass of chromatin, surrounded by a layer of nucleoplasm, with a firm outline. They are spherical or slightly oval bodies, a little larger than the nuclei of the mycelium.

EXPLANATION OF FIGURES IN PLATE VI.

Illustrating Mr. Harold W. T. Wager's paper on the Structure of the nuclei in *Peronospora parasitica.*

Fig. 1. Nuclei of the mycelium in various stages of division. × 1500[1].

Fig. 2. Nuclei of the oogonium in various stages of division. × 1500.

The numbers in the above figures denote the successive stages of division.

Fig. 3. A small piece of the mycelium, showing nuclei at the time when the mass of chromatin is beginning to break up. × 1000.

Fig. 4. Section of an oogonium just forming as an expansion at the end of a hypha. Numerous nuclei, *n*, in the resting stage have just passed into it from the mycelium. *a*, antheridium. × 1000.

Fig. 5. Section of an oogonium and antheridium which have just been delimited from the thallus. The nuclei are slightly enlarged, and the chromatin is somewhat broken up. × 1000.

Fig. 6. Section of an oogonium at a little later stage than Fig. 5; the nuclei are larger and the thread structure is distinctly visible. Numerous vacuoles, *v*, are present. × 1000.

Fig. 7. Section of an oogonium with its antheridium at the time when the nuclei are passing to the periphery of the oogonium. × 1000.

Fig. 8. Section of an oogonium with its antheridium. The nuclei are arranged very regularly in the periphery of the oogonium. The central portion of the oogonium contains a quantity of less dense protoplasm. *a*, antheridium. *p*, periplasm. *o*, protoplasm of the oosphere. × 1000.

Fig. 9. Section through the peripheral portion of an oogonium at the stage shown in Fig. 8 so as to include a complete layer of the nuclei. The nuclei exhibit a thread structure, many of them in the stage just previous to division. Some very faint conical, slightly-stained masses, *s*, probably of the nature of a nuclear spindle, are to be seen in connection with many of them. *n*, nucleus seen from the end. *n'*, nucleus seen slightly oblique. × 1500.

Fig. 10. Section of an oogonium in which the peripheral nuclei have begun to divide. Three of the small nuclei, *n*, can be seen passing towards the centre of the oogonium, where they probably fuse together. × 1000.

Fig. 11. Section of an oogonium in which the peripheral nuclei have divided up into a number of smaller nuclei, *n'*. The wall of the oosphere, *o*, is just beginning to form, and appears as a somewhat granular layer, just inside the layer of periplasm, *p*. The nuclei of the antheridium, *a*, have also divided up in the same manner. *a'*, antheridial tube. A single nucleus, *n*, is seen in the protoplasm of the oosphere.

[1] Except where otherwise stated the figures have been drawn by means of the camera lucida and the apochromatic object-glasses of Zeiss.

Fig. 12. Another section of the oogonium shown in Fig. 11, showing a second nucleus in the protoplasm of the oosphere. Letters as in Fig. 11. In this section the antheridial tube is not visible. × about 800, Swift's $\frac{1}{16}$ water-immersion.

Fig. 13. Section of an oogonium with the antheridial tube in connection with the oosphere. The antheridial tube contains a single nucleus, *n*. The wall of the oosphere, *o*, is now distinctly seen. × 1000.

Fig. 14. Section of an oogonium and antheridium just before fertilisation takes place. The antheridial tube, *a'*, contains one nucleus, *n*, near the end of its swollen part. The oosphere contains a single nucleus, *n'*. × 1000.

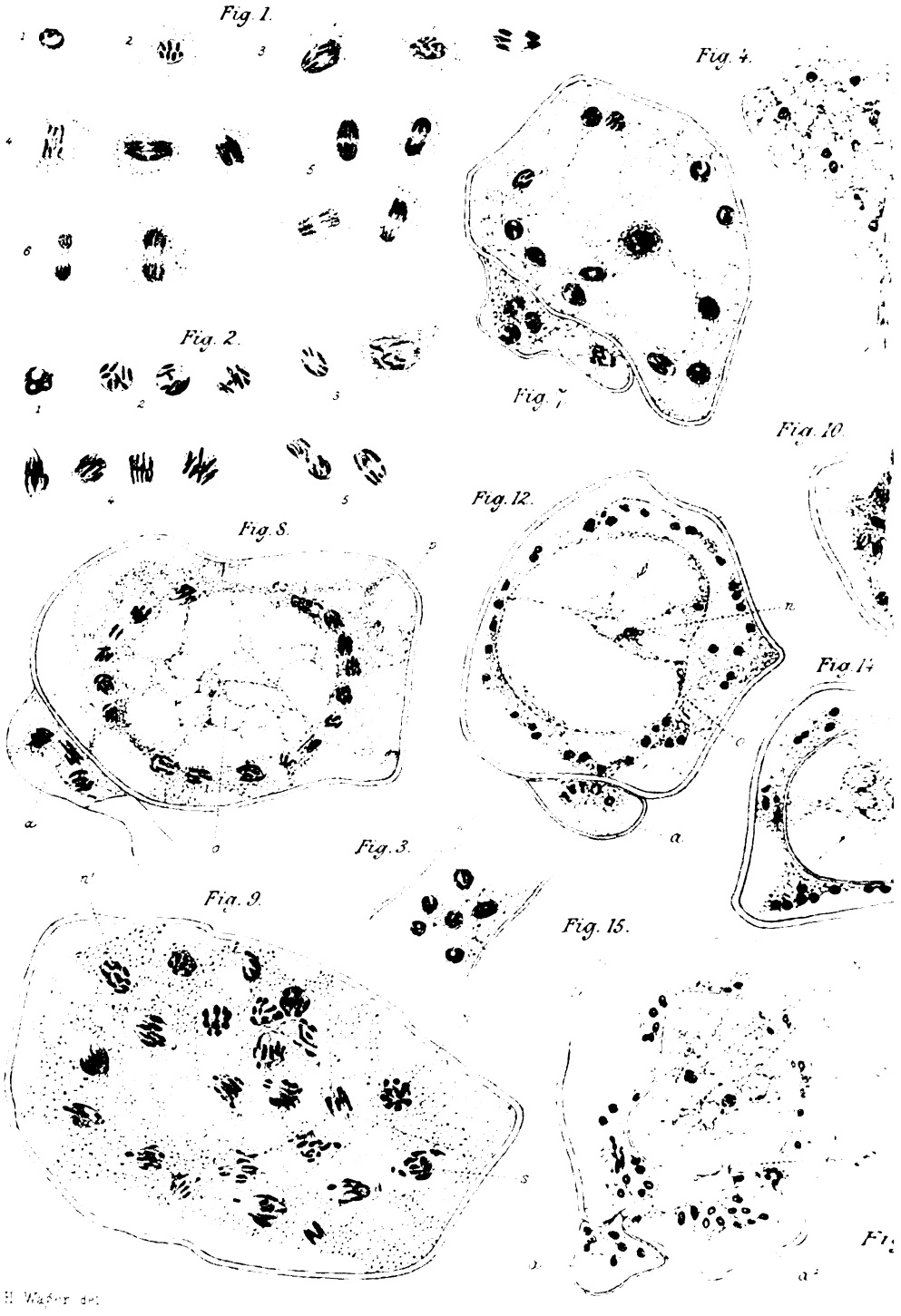
Fig. 15. Section of an oogonium after fertilisation is supposed to have taken place. The antheridial tube is seen to open into the oosphere by a small hole, *f*, placed very near the end of its swollen portion. The antheridium contains a number of nuclei, and the oospore, *o*, contains two very faintly stained nuclei, *n*. × 1000.

Fig. 16. Section of an oogonium with its antheridium, *a*, showing the antheridial tube, *a'*, much contracted. × 1000.

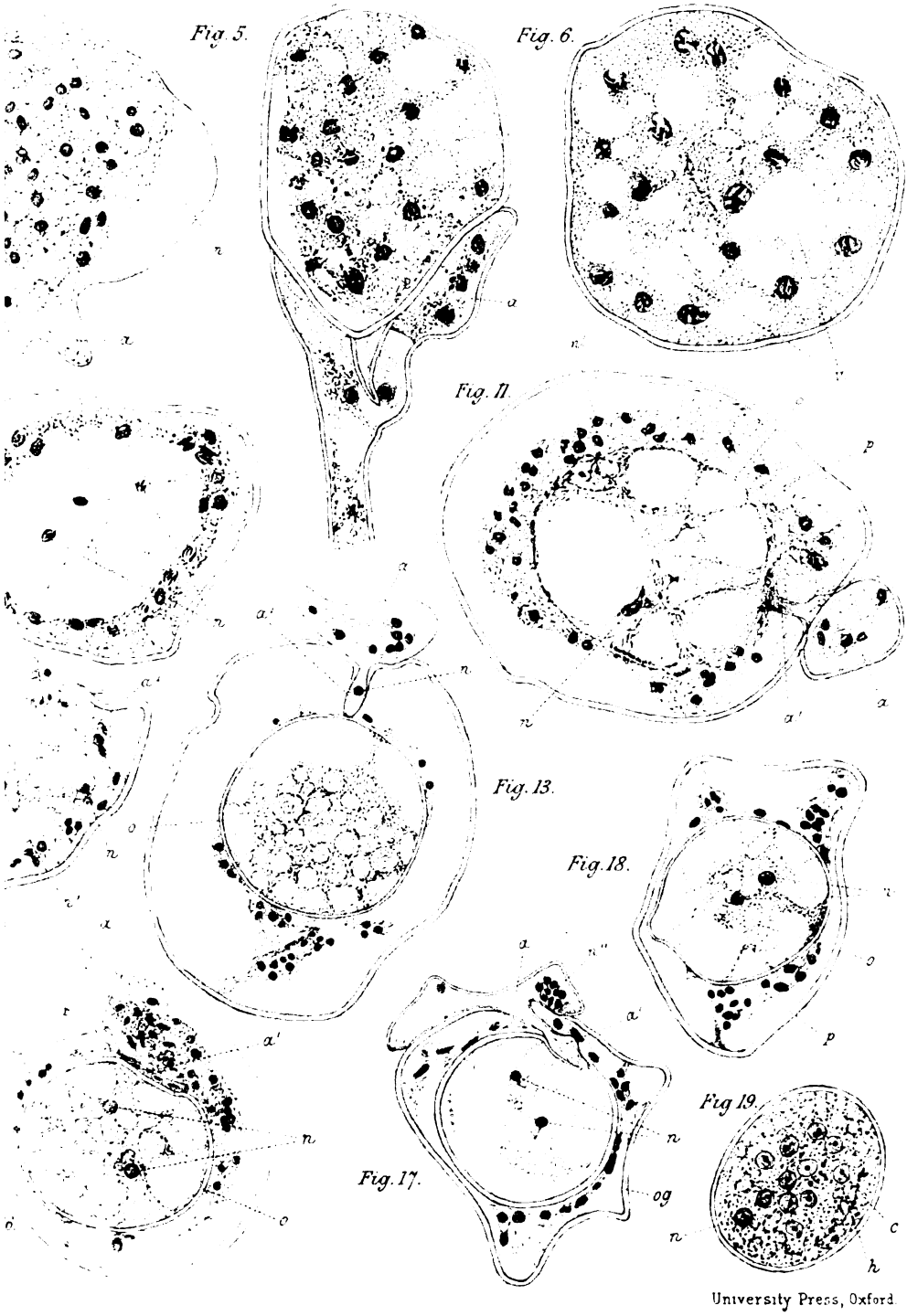
Fig. 17. Section of an oogonium, with its antheridium, *a*, in a much later stage. The wall of the oogonium, *og*, is much contracted, and the antheridium and tube, *a'*, are becoming disorganised, the former still containing a number of nuclei, *n''*. × 1000.

Fig. 18. Section of an oogonium in a much later stage. Two nuclei, *n*, are still to be seen in the oospore, *o*, the periplasm, *p*, has become less granular and is more hyaline, and is gradually forming a dense compact layer on the wall of the oospore, the periplasmic nuclei at the same time becoming disorganised. × 1000.

Fig. 19. Section of a gonidium of *P. parasitica* showing numerous nuclei the structure of which is different from the nuclei of the mycelium and oogonium; *k*, slighlty stained nucleoplasm surrounding a central mass of chromatin, *c*. × 1000.



WAGER.—ON NUCLEI IN PERONOSFORA PARASITICA.



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On some recent progress in our knowledge of the Anatomy of Plants[1].

BY

D. H. SCOTT, M.A., Ph.D., F.L.S.,

Assistant Professor in Botany, Normal School of Science and Royal School of Mines.

IN plants, Anatomy, which may be defined generally as the study of internal structure, cannot be sharply separated from Histology. The investigation of the coarser structure, though a necessary preliminary, would be wholly barren without a knowledge of the tissues of which the organs of plants are composed, for it is to special tissues, and often even to isolated cells, that special functions are attached. Take, for example, the fibro-vascular bundles, no idea of the numerous functions which they discharge could be formed without a knowledge of their minute structure.

In this paper, however, the finer Histology, relating to details of structure of the individual cell, will be excluded.

The anatomy of plants is a branch of botany in which Englishmen may claim a special interest. Nehemiah Grew's 'Anatomy of Plants,' 1682, is a wonderful record of early microscopic research, and it is interesting that the 'Anatome Plantarum' of his Italian contemporary, Malpighi, was communicated to the Royal Society of London.

It is, however, only with the recent progress of the subject that we are now concerned.

As regards the vegetative anatomy of the higher plants, we may take de Bary's great work, published in 1877, as our

[1] Read before Section D at the Newcastle meeting of the British Association for the Advancement of Science.

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starting-point. No attempt will of course be made to summarize all that has been done since that time. My object is only to call attention to some of the most striking advances in our knowledge, especially in the hope of showing how much room there is for further fruitful research in this field.

Classification of tissues. This may rest on a purely anatomical, a developmental, or a physiological basis. In de Bary's work the first principle is adopted, i. e. histological elements are classified in the main according to their mature structure, though the separate treatment of secondary tissues is so far a concession to the developmental method. The latter principle is impossible to carry out consistently, owing to the fact that in the embryonic tissues distinct histogenetic layers cannot always be distinguished.

The physiological method of classification is characteristic of the present period of anatomy, and has been applied in a thoroughgoing way by Haberlandt. This tendency dates from Schwendener's 'Mechanical Principle in the Structure of Monocotyledons,' 1874; and culminates in Haberlandt's 'Physiological Anatomy of Plants,' 1884. The attempt to classify all tissues by their functions suffers under two disadvantages. Firstly, it is premature, our knowledge of function being still so imperfect. Thus there is a danger of the classification being based on doubtful hypothesis, e. g. Haberlandt's inclusion of laticiferous tubes under conducting tissues. Secondly, it has been carried out somewhat pedantically, e. g. his treatment of the stomata as belonging to a different tissue-system from the epidermis. This might indeed have been avoided by defining dermal structures as those which regulate the communication between the plant and its environment. The work of the Schwendenerian school has, however, added immensely to the interest of anatomy, as we shall see in detail further on.

Beginning with the dermal tissues as just defined, the subaërial epidermis has long been among the best known tissues, and the points of progress we have to note are rather physiological than strictly anatomical. Westermaier's dis-

covery (1883) that the epidermis often acts as a water reservoir, may be mentioned. In the case of a many-layered epidermis, such as that in Piperaceae, his experiments are decisive, but it is very doubtful whether this view applies generally. As regards its origin the aqueous tissue does not of necessity belong to the epidermis at all, and thus we here have a good illustration of the difference between developmental and physiological classification of tissues.

Then we have Mr. F. Darwin's interesting explanation of the function of the waxy layer of the cuticle in preventing the wetting of the stomata, while as regards epidermal appendages Haberlandt's very beautiful exposition of the structure and mode of action of stinging hairs may be noticed. Our knowledge of epidermal glands, and especially of extra-floral nectaries, has greatly increased, but this is a subject which has been dealt with elsewhere at this meeting.

The dermal tissues of *roots* have been the subject of much interesting research. What we generally term epidermis is here an absorptive structure, but this is only the case in *young* roots. The older roots cease to be absorptive and require, like sub-aërial organs, a protective dermal structure. Olivier, especially, has shown how this protection is afforded by the outermost cortical layer, which becomes cuticularized and often exactly simulates a true epidermis, while the absorptive layer withers away. This epidermoidal layer, or better *exodermis*, is especially evident in monocotyledonous roots, which have a persistent cortex, and often no periderm, so that the exodermis here has to form a permanent protective structure. This does not, however, hold good of all Monocotyledons, for Olivier has shown that many of them develop a true external periderm on their older roots, whether aërial or terrestrial, e. g. Aroideae, Liliaceae, etc.

The distinction formerly drawn in this respect between the roots of the two classes of angiosperms has been further broken down by Olivier's discovery of an *external* periderm in many dicotyledonous roots (Ranunculaceae, Gentianeae, Primulaceae, etc.).

In certain roots the periderm is specially modified to enable them to act as organs of respiration, as in the roots of *Avicennia* and *Sonneratia* described by Goebel. Similar structures have been observed by Jost in certain palms, etc., and the peculiar spongy periderm of the floating roots of *Sesbania* may also perform respiratory functions.

Assimilating tissues. There is evidence that the palisade-tissue does on an average three to four times as much assimilating work as the spongy parenchyma. Stahl has shown that the palisade-cells are the form better adapted to high and the spongy cells to low intensities of light. Evidence of this is found in the phenomena of epistrophe and apostrophe, and in the variations in development of palisade-parenchyma according to the degree of exposure, as in the sun-leaves and shade-leaves of the Beech. Corresponding changes have been observed by Stahl in the leaves of 'Compass plants.'

Pick's experiments showed that the length of palisade-cells varies with the intensity of light, and that the inclination of their long axes depends on the direction of the incident rays. His experiments also demonstrate a different organisation of the chlorophyll-containing tissues on the north and south sides of assimilating stems.

Haberlandt's view that the form and arrangement of palisade-cells are adaptions for the direct conduction of assimilated food appears to be only of limited application.

The absence of differentiation of the mesophyll in chlorotic, and therefore non-assimilating leaves is worth noticing here.

Mechanical tissues. Schwendener's exposition of the principles on which these tissues are arranged, especially in Monocotyledons, may be assumed to be familiar. It is remarkable that these elaborate adaptations are confined to organs destitute of secondary thickening. In the stems of dicotyledonous trees, especially those with heart-wood, the most effective mechanical tissues usually lie towards the middle of the stem. There is a tendency among physiological anatomists to make mechanical adaptation explain too much. Haberlandt's explanation of the medullary zone of

wood in *Tecoma* as an adaptation of the climbing stem to tensile strains is a case in point. As a matter of fact, the internal wood is extremely porous and evidently in the main a conducting-tissue of little mechanical importance. As regards development, the mechanical tissue may arise from all regions of the meristem, and here there is consequently a sharp opposition between the developmental and physiological principles of classification.

Secretory tissues. On this subject much work has been done.

The widely-distributed secretory sacs appear to have become modified in certain orders in two directions, namely, into laticiferous vessels and laticiferous cells. The discovery that the latter are living elements with protoplasm and nuclei is due to Treub, Schmidt, etc.

The function of laticiferous tissue is supposed by Haberlandt to consist in the conduction of assimilated food. The observations of Schimper, Groom, Boodle, etc. show, however, that the relation of these tubes to the assimilating system is not a constant one.

The very early development in embryonic tissues is common to laticiferous tubes and certain secretory sacs.

As regards intercellular secretory *spaces* these differ from the sacs in the fact that the secretion leaves the cell in which it is formed. The distinction between lysigenetic and schizogenetic spaces depends on the fact that in the former the cells become completely used up in the process of secretion, while in the latter the same cells remain living and may continue their functions indefinitely.

The schizogenetic mode of origin appears to be much more usual than has been supposed, and very probably all secretory spaces begin in this way, e. g. Rutaceae and Myrtaceae. In the glands of *Myoporum* the cells fuse, their nuclei remaining for a time distinct.

Vascular bundles. As regards the main points in the distribution of bundles there is little to add to the elaborate account of de Bary. The curious parallelism discovered by

Professor Bower between the lobeliacious *Rhynchopetalum* and the Cycads may be noticed.

Internal phloëm is characteristic of a large number of dicotyledonous orders, usually, though not always, very highly organized ones, e.g. Myrtaceae, Onagraceae and all allied orders, Campanulaceae, Compositae, Cucurbitaceae, etc. Our knowledge of this interesting advance on normal dicotyledonous structure has been much increased by the work of Vesque, Petersen, Weiss, Solereder, and Hérail. The internal phloëm may occur as a constituent part of the normal bicollateral bundles, as distinct phloëm strands, or as a part of complete medullary bundles. Weiss has distinguished between the internal phloëm of bicollateral and that of medullary bundles, by differences in the distribution and in the time of development, but in *Campanula* and the Melastomaceae all transitions occur between the three cases mentioned above. The internal phloëm very often has cambial increase like the normal tissues.

Weiss's discovery of tertiary bundles in the xylem-parenchyma of fleshy roots and Treub's account of the adventitious bundles which replace the normal vascular system in *Myrmecodia* afford striking illustrations of the plasticity of dicotyledonous structure.

Closely connected with the peculiar structure just considered are some of the modifications of secondary thickening. This process in general may, I think, be regarded with advantage from a point of view similar to that of Alex. Braun, in his 'Rejuvenescence in Nature[1].' We are sufficiently familiar with the benefits afforded by secondary growth in increasing the area of the conducting and mechanical tissues in proportion to the increasing surface of foliage. But evidently this is not the whole explanation; secondary formation of new elements often takes place without any immediate increase in the mere quantity of tissue. The phloëm-islands of *Strychnos* go on forming new cells from their special cambium long after the wood has completely closed in around

[1] See p. 121 of the Ray Society's translation.

them. Hence the new elements simply compress and obliterate the old. The same is the case with medullary phloëm whenever it has cambial increase, and further illustrations may be drawn from the anomalous bundles, imbedded in sclerotic tissue of the Chenopodiaceae and allied families. Again, in the vine, for every year's new growth of phloëm the produce of a previous year is thrown off. As regards mere increase in quantity of tissue there is in all such cases a great waste. I believe the explanation is to be sought in the principle thus formulated by Weismann (p. 21, English edition):—'The vital processes of the higher animals are accompanied by a renewal of the morphological elements in most tissues.' So I believe it is with the most highly organized plants in the majority of classes, and especially the Dicotyledons and Gymnosperms. The renewal of tissue, the replacement of effete, overworked elements by new and energetic ones, is an end in itself, apart from the mere increase of tissues in bulk. The principle is the same as in the more obvious case of the replacement of old leaves by fresh ones.

It is remarkable for how long a time the same elements must continue functional in the stem of trees (such as palms) without secondary growth. This is really an exceptional case among organic beings.

The subject of anomalous thickening in Dicotyledons suffers in interest from our bald and meagre knowledge, especially of the development. The study of such profoundly modified structures in the culminating class of the vegetable kingdom must lead eventually to interesting results. We already have real progress to note.

In a group of families including the Chenopodiaceae, Nyctagineae, and Amaranthaceae we have a conspicuous anomaly consisting in the appearance of extra-fascicular cambium, either in the place of or in addition to the normal layer. This extra-fascicular zone may either be permanently active, producing ring after ring of collateral bundles, or its function may cease after one such ring has been formed, its place being taken by a new zone of cambium arising once more

in the tissue lying outside the bundles already developed. Until quite recently it has been supposed that these anomalous cambial layers differ essentially from normal cambium in the fact that the bundles which they form are produced in their entirety on the *inside* of the meristematic zone, the development of all their elements being thus centrifugal. This is the view of de Bary and van Tieghem, the former of whom speaks of the phloëm in all these cases, on account of its supposed centrifugal development, as forming part of the wood.

The investigations of Morot and Hérail (1885), with which many independent observations of my own agree, have shown that this view is wholly incorrect. Extrafascicular cambium acts precisely like normal cambium, producing wood internally and phloëm externally. In those cases where the same zone appears to be permanently active it is really completed after the formation of each bundle by the appearance of a new cambial arc outside each new phloëm group. Hence there is no need for the paradoxical terminology formerly used, and these cases are rendered more easily comparable with normal development. The analogy with such Monocotyledons as *Dracaena* probably led the earlier observers wrong; in these latter cases the process is essentially different from dicotyledonous thickening, as the entire bundles arise inside the so-called cambium. In *Strychnos* again, as has been shown by Hérail and by myself and Mr. Brebner, the remarkable phloëm-islands are formed like normal phloëm centripetally outside the cambium, and subsequently become enclosed in the wood by means of a new cambial arc completing the normal zone.

Phloëm-islands imbedded in the wood are now known to occur in at least twenty-four genera belonging to ten natural orders. In some of these, as in *Salvadora*, the development appears to be really centrifugal. In the great majority of cases, however, whether normal or anomalous, cambium produces wood only on one side, bast only on the other.

Many anomalies of structure in Dicotyledons have been

correlated with a climbing habit. In some cases, as in the Bignoniaceae and Sapindaceae, this explanation certainly holds good. But there are many points in which it breaks down, as Hérail has shown. Further investigation is urgently needed to enable us to understand fully the physiological significance of these highly modified structures.

The recognition of the *pericycle* as a special zone of tissue immediately surrounding the bundle-system in both stem and root is due to the French botanist Morot. This layer, long known in roots as the 'pericambium,' is of interest from the fact that it is the seat of new formation of tissue of all kinds, as of lateral and adventitious roots, internal periderm, and extrafascicular cambium.

The time has, I think, come when we must return to the view that the vascular cylinder of the root should be regarded as a bundle-system (in some roots enclosing a pith), and not as a single bundle. The term 'radial bundle' may be convenient, but it suggests a false comparison. The central cylinder of the main root is perfectly continuous with the bundle-system and pith of the stem, and in many cases the anatomical peculiarities of the one organ extend into the other. The same principle must obviously be applied to lateral and adventitious roots also. The change will involve some revision of our terminology, but it is necessary if the anatomy of the root is to be made clear.

Before leaving the general structure of the vascular bundle, Haberlandt's discovery that the finer bundles in the leaves of ferns are collateral, not concentric, may be noticed. This is interesting as helping to establish the correlation between collateral structure of the bundle and bifacial organization of the leaf.

The question of the cause of annual rings in wood is too purely physiological to be dealt with here. We are still in want of a satisfactory explanation to replace that of de Vries, but we can hardly be wrong in correlating the formation of new porous spring-wood in each year with the increased transpiring surface of the foliage.

On the *sieve-tubes* and soft bast generally an immense amount of work has been done; of purely anatomical results Wilhelm's discovery of horizontal sieve-tubes traversing the medullary rays and Fischer's observations of a transitory system of sieve-tubes external to the bundles in Cucurbitaceae are of special interest. The latter author has also taught us how to study the contents of the sieve-tubes in their natural state.

It seems that the characteristic contents of the sieve-tubes appear when their members are still closed cells, a point in favour of Sachs' view, that they may be seats of metabolism rather than mere channels of conduction. May I suggest as an hypothesis, that the companion-cells may be *secretory*, supplying the sieve-tubes with those ferments by which the starch-grains, and perhaps proteids also, are brought into a soluble condition? In the first place, the companion-cells, with their exceptionally dense granular protoplasm and conspicuous nuclei, have all the characteristics of secretory cells, such as those of nectaries, water-glands, and the epithelium of resin-canals. Secondly, we know from Fischer's work that the companion-cells communicate with the sieve-tubes by protoplasmic strands. Thirdly, we know that ferments are actually present in the sieve-tubes, as is shown by Russow's observation of the peculiar reaction of their starch grains indicating diastatic action. In those plants where the companion-cells are numerous, the comparison with an epithelium at once suggests itself.

Within the last three years attention has specially been directed to sliding growth or the changes in the form and relative positions of cells during their development. This process, which plays so important a part in the formation of most tissues of all highly organized plants, had previously been almost ignored. The subject has been dealt with already elsewhere; I will only say a word as to a special case bearing on this question. The secondary xylem of Monocotyledons, such as *Dracaena*, consists chiefly of very elongated elements, usually classed as tracheides. Krabbe has maintained that

each of these tracheides is developed by the enormous elongation of a single cambial cell, which would involve a very striking instance of sliding growth; on the other hand, Kny has found, that the so-called tracheides are in reality short vessels arising by the fusion of series of cambial cells. I have been at some pains to investigate this question, and though my work is far from complete I have satisfied myself that cell-fusion does actually occur, while at the ends of the fused rows of cells and sometimes at other points independent growth goes on. The free ends of the immature vessels contain abundant protoplasm, when the rest of the tube appears empty; both this fact and the finely tapering, sometimes hair-like points of the vesssls show that some independent sliding growth must take place. Occasionally a lateral branch arises in the same way. The fact that growth of this kind takes place was recognized by Kny. The occurrence of sliding growth in connection with cell-fusion is already familiar in the case of many laticiferous vessels.

Much has been done lately on the subject of the apical meristem. The theory of germinal layers in plants, founded on Hanstein's discovery of plerome, periblem, and dermatogen, has not been able to maintain itself, for even in the highest plants these layers are by no means always distinct. As pointed out by Sachs, the apical meristem is that part of the plant which remains in the embryonic condition. Where we have either a single apical cell or a group of equivalent initial cells, we may regard the protoplasm of the growing point as still retaining the properties of the germ-plasm; where, however, distinct histogenetic layers are present at the apex, their cells are already in the way to become somatic in so far as they are predestined to give rise to special tissues only. From this point of view it seems clear that an apical cell is qualitatively different from the segments which it cuts off, and therefore Sachs' conception of this cell as a mere gap in the system of cell-walls in the growing-point cannot, I think, be any longer accepted as sufficient.

On the closely allied subject of the origin of lateral and

adventitious *roots* an extensive work by Van Tieghem has recently appeared. His elaborate investigations appear to show that the facts are simpler than has been supposed, all Phanerogams agreeing in the origin of lateral roots from the pericycle, while in the Vascular Cryptogams they are formed entirely from the endodermis. To the latter rule, however, *Lycopodium*, *Selaginella*, and *Isoëtes* are exceptions.

It has, I think, been shown that active progress has been and is going on in the study of the vegetative anatomy of vascular plants. But this by no means exhausts the field of anatomical research. Very striking advance has recently been made in our knowledge of the internal structure of other classes of plants, and especially of the Algae and Muscineae. As regards the former class I need only call attention to the discovery of sieve-tubes in the larger brown Algae. The work of Parker, Will, and Oliver has shown that these structures are in all respects comparable to the sieve-tubes of the highest plants—a surprising result, which by itself is sufficient to show that the term 'cellular plants' can no longer be applied generally to the Algae. There can be no doubt, that further investigation will bring to light a very high differentiation of tissues in some of these plants.

In the Mosses also we have learned, especially from the work of Haberlandt and the late Mr. Vaizey, that the tissues are much more highly organized than was supposed before. In many members of the class the existence of a conducting system, differentiated into tissues functionally corresponding to xylem and phloëm, has been clearly demonstrated.

The anatomy of the structures connected with reproduction is a branch of investigation which has in recent times been much neglected. The study of the development and structure of the *complex fruits* of the higher plants is an especially promising field of work, in which I am glad to say a beginning has already been made.

The importance of anatomical characters in classification has been the subject of much discussion. It is, I think, perfectly evident, that internal structure must be taken into

account in any natural arrangement, but the high adaptability of anatomical characters is a great difficulty. Only the most thorough comparative research, in which development on the one hand and biological conditions on the other are regarded with equal attention, can lead to trustworthy results here. Bicollateral structure of the vascular bundles, extrafascicular cambium, and certain forms of the secretory apparatus are already known as characters of some systematic value. But too much of the work on this subject has been superficial and therefore barren. The mere cutting of a few sections from imperfect herbarium specimens will never suffice for a scientific investigation, nor, on the other hand, are any valuable results likely to be attained by those who lose themselves in details without any appreciation of the relative importance of the facts observed.

It need scarcely be pointed out how important an adequate knowledge of anatomical characters should be from a palaeontological point of view.

In conclusion, a word may be said on method. So far the mechanical section-cutting, which has led to such important results in Zoology, has been but little used in our science. But I am sure that here also the more primitive methods will have in many cases to give way. Manual skill will always be of importance, but it should be economized, and when equal or better results can be obtained with far greater certainty by mechanical methods, the latter should I think be adopted. My own experience has taught me that the microtome and the methods connected with it may be applied with great advantage to botanical research.

The study of the anatomy of plants, so far from being an exhausted subject, promises in the future to lead to far more interesting results than in the past. United on the one hand with Physiology and on the other with General Morphology, Anatomy will cease to be a bare record of dry facts, and will afford the most important contributions to our understanding both of the life of the individual plant and of the vegetable kingdom.

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It need scarcely be said that the above short list makes no pretension whatever to completeness. It simply contains, in alphabetical order, the titles of works directly referred to in the text.

NOTES.

A NEW APPLICATION OF PHOTOGRAPHY TO THE DEMONSTRATION OF CERTAIN PHYSIOLOGICAL PROCESSES IN PLANTS.—It is possible by taking advantage of their sensitiveness to light, to obtain prints from *Protococci*, or the free swimming swarmspores of many green Algae. Into one end of a water-tight box, a thin glass plate is securely fitted. The negative to be printed is then placed next the glass, film-side nearest. The box is filled with water containing a fairly large quantity of swarmspores. The lid is shut down, and the whole is exposed to diffused light. In the case of a strong and well-developed negative, the swarmspores swim towards the most highly illuminated parts, and there in the greatest numbers come to rest, and settle upon the glass, so that after some four or six hours, on pouring out the water and removing the negative, a print in green swarmspores can be obtained. The print is dried, fixed with albumen, stained, and varnished. Whatever is the exact chemical nature of the synthetic formation of proteid and protoplasm which takes place in the chlorophyll-corpuscles of plants under the influence of light, this is at least clear, that the first *visible* product of the assimilatory activity is the starch found in the corpuscles. The presence of this starch can be made manifest by treating a decolorised leaf with a water solution of iodine dissolved in potassic iodide. If a plant (and preferably a plant with thin leaves) be placed in the dark overnight, and then brought out into the light next morning, the leaves being covered with a sharp and well-developed negative, starch is formed when light is transmitted, and in greatest quantity in the brightest areas. Thus a positive in starch is produced which can be developed by treatment with iodine, and it might be possible to obtain a permanent print, by suitable washing, and treatment with a soluble silver salt, silver iodide being formed.

WALTER GARDINER, Cambridge.

DOUBLE-FLOWERED CEANOTHUS.—A double-flowered Rhamnad has, so far as I know, not hitherto been recorded; at least, no such case is mentioned in Dr. Dammer's recent German translation of my Vegetable Teratology, in which numerous additions have been made, both by the translator and myself, to the records given in the original edition. It may, therefore, be worth mentioning that among some garden varieties of *Ceanothus* that have lately come under my observation, there were several 'double' forms. The mode of doubling in each case was similar. Each flower had a calyx of five sepals as usual, then five petals of the ordinary, long-stalked, spoon-shape. In front of each of these was a similar petal representing the stamen of an ordinary flower. Both sets of petals sprang from the outside of a thickened annular disc lining the base of the calyx. Within the disc there was no pistil, but in its place a tufted mass of imbricating, petaline scales arranged around a slightly prolonged axis.

The arrangement of the outer parts of the flower may be understood by the following formula:—

S S S S S
P P P P P
P P P P P

The inner row of petals thus exactly corresponds in position with the stamens of an ordinary flower. Eichler attributes the superposition of the stamens to the petals in Rhamnads to the suppression of an outer row of stamens, but in no genus of *Rhamnaceae* is any second row of stamens mentioned. An examination of the flowers in question leads me to suggest that the petals and stamens are not in this case autonomous organs, but that the one is an outgrowth from the other. This can only be determined by a more complete investigation of the course of development and the study of the anatomy and distribution of the vessels than I have been able to make. In any case, the 'doubling' of the *Ceanothus* flower is brought about by the petalisation of the stamens, the suppression or non-development of the pistil, and by the median-prolification of the flower. Whether mites had anything to do with the production of these double flowers I am unable to say, my testimony is simply to the effect that I did not find any. Indeed, Peyritsch's experiments need to be confirmed by other observers before they can be considered as conclusively proving the agency of mites in

the formation of double flowers. I am familiar with certain changes which appear to be the result of the action of mites (Phytopti), such as a preternatural development of scales, but I have not been led at present to co-relate the injuries inflicted by mites with the development either of Peloria or of double flowers.

MAXWELL T. MASTERS, London.

ON DR. MACFARLANE'S OBSERVATIONS ON PITCHERED INSECTIVOROUS PLANTS.—While recognising with much satisfaction that Dr. Macfarlane's examination of the pitcher of *Nepenthes* has led him to conclusions which are in part similar to my own[1], I think it is nevertheless necessary, to point out that our views are by no means coincident, and the difference depends upon a certain fundamental factor in morphological method.

The chief point on which we agree is that the lid of the pitcher of *Nepenthes* is the result of congenital coalescence of two pinnae; but I regard these as the only pinnae formed by the winged phyllopodium, while Dr. Macfarlane says, 'We may fairly view a *Nepenthes* leaf as being compound, and composed of from three to four or five pairs of leaflets disposed along a midrib, and that both leaflets and midrib undergo striking modifications, the leaflets especially showing a marked tendency to dorsal fusion above.' Dr. Macfarlane further constructs a diagram (Fig. 7), and explains (p. 259) that he regards the lid as the result of coalescence of the *third* pair of pinnae, the two lower pairs being represented by the regions marked (*b*) and (*c*) in his diagram. In my view, however, the lateral flaps which he regards as pinnae are merely developments of those wings, which are to be seen here, as in so many leaves from the Ferns upwards, traversing the whole length of the phyllopodium longitudinally, and I base this view upon the fact that these wings are visible as smooth flanges in very early stages of development, there being (with the exception of the young lid) no rounded and projecting outgrowths upon them which could be recognised as pinnae. The study of the external form and internal structure of the mature leaf cannot suffice to substantiate such a view as that of Dr. Macfarlane. In order to support his view it will be incumbent upon him to show that distinct rounded outgrowths do appear on the wings of the young leaf; but he does not give any such evidence, nor do my own observations or those of Sir J. Hooker

[1] Annals of Botany, vol. iii, p. 239, and p. 253.

lend any support to his view. I therefore conclude that the lid of the pitcher represents the first pair of pinnae. Dr. Macfarlane further regards as pinnae those lateral growths which appear upon the terminal spur; these had not escaped my attention (p. 243, also Figs. 8, 16, Plate XVI); but the irregularity of their occurrence, their form, and their arrangement make me doubt their being of the nature of pinnae.

The adoption by Dr. Macfarlane of a view of the leaf of *Nepenthes*, which on the above grounds I think is a mistaken one, has led him to an equally erroneous interpretation of the leaf of *Sarracenia*. He would regard this also as a compound leaf, and especially he would take the dorsal (or adaxial) flap, which is often so marked a character of the leaf, to consist of 'opposite leaf-lobes whose faces are not only applied to each other, but organically fused;' as support of this conclusion he examines the development, and especially the vascular arrangement.

Fig. 1.

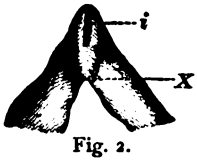

Fig. 2.

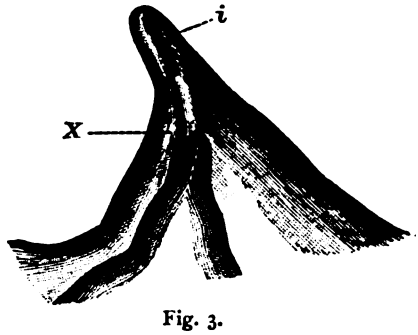

Fig. 3.

Figs. 1, 2, 3 show successive stages of development of the leaf of *Sarracenia flava*. *i*, involution to form the pitcher. *X*, the upper limit of the sheath.

In criticising this conclusion I would first remark that the absence of distinctive evidence from external form is an objection to such a view. I have examined young leaves of *Sarracenia flava* (Figs. 1, 2, 3), and do not find at any point upon them any formation of such rounded and distinctly convex growths as we associate with the term leaflet, or pinna; nor does Dr. Macfarlane himself mention or figure any such. The leaf is, however, a winged one, and the wings are developed at its base so as to form a sheath, the wings converging and terminating at the upper limit of the sheath (*X* in Figs. 2, 3); the part above this is not distinctly winged; towards the apex an

involution occurs (*i*), as in *Nepenthes*, and between this and the upper limit of the sheath there appears a median, slightly projecting longitudinal ridge, which ultimately develops into the median adaxial flap. It appears at first as a simple ridge, and I see in its development no ground for concluding that it 'results from fusion of two leaflets[1].' Dr. Macfarlane has sought for support of his view as to its compound character in its internal structure, and has cited the case of *Iris*, saying that the leaf of *Iris* has long been known to be composed of 'opposite leaf-lobes, whose faces are not only applied to each other, but organically fused.' But this view is surely altogether a thing of the past, since Goebel demonstrated[2] that in its development the leaf of *Iris* shows no indication of a composite nature; the ensiform portion is rather to be regarded as an outgrowth of the abaxial side of the leaf, which far overtops its organic apex. I have elsewhere pointed out[3] that anatomical evidence is insecure, and in the absence of evidence from external form, the mere fact of the arrangement of the vascular bundles being such that their xylem-masses face one another is quite insufficient foundation for a hypothesis of origin by cohesion of parts. Moreover, in the case of the phyllodes of various species of *Acacia*, the arrangement of the vascular bundles is similar to that in *Iris*, or in the flap of *Sarracenia*; if the vascular arrangement is to be admitted as evidence of coalescence in *Sarracenia*, these leaves also would demand a similar explanation, which in *Acacia* appears even less probable than in those above quoted.

I conclude therefore that a hypothesis of cohesion is unnecessary for the explanation of the adaxial flap of the leaf of *Sarracenia*, it would appear to me to be a simple outgrowth in a radial plane, somewhat similar to that of the leaf of *Iris*, or the phyllode of *Acacia*; at all events, its formation by coalescence of *leaflets* or *pinnae* is out of the question in the absence of any evidence for such a view in the conformation of the young leaf.

As regards the lid in *Sarracenia*, I see no reason to think this is more than a simple flattened apex of the leaf; neither the development nor the mature structure gives sufficient evidence of a compound nature. Thus I should conclude that the leaf of *Sarracenia* is throughout a simple phyllopodium, consisting of (1) a basal sheathing portion, (2) a middle portion which may be hollowed by involution of the upper surface, and

[1] L. c. p. 262.

[2] Bot. Zeit. 1881, p. 96.

[3] Annals of Botany, vol. i, p. 134, etc.

bear upon its upper surface a phyllodineous flap; and (3) the lid, which is the simple flattened termination of the leaf. It will thus be seen that in *Sarracenia* as in *Nepenthes* Dr. Macfarlane's interpretation of the leaf is more complicated that my own. The discrepancy of our views depends chiefly upon a difference in the way of drawing the distinction between the wings and the pinnae produced upon the wings; Dr. Macfarlane would appear to recognise any convexity of margin of the wing, however slight, and however late in its appearance, as a leaflet or pinna, whereas I should reserve these terms for only such growths as arise at an early period in definite order upon the wings, and appear as convexities with a clearly defined contour. Pursuing his less rigorous method, Dr. Macfarlane finds himself landed in a view as to these leaves which is too unwieldy to appear natural; my own interpretation has at least the quality of relative simplicity.

On first putting forward my views as to the morphology of the leaf, I recognised that difficulties might present themselves in drawing a distinction between a wavy contour of the wings and the pinnae which may be produced upon the wings, and that it might be argued that such a distinction could not be clearly defined[1]; it is obviously impossible to lay down exactly a limit of that curvature of contour which shall be recognised as characteristic of the pinnae, and say that any curvature of greater radius should be regarded as a mere wavy growth of the wing; nevertheless with regard to the leaves above discussed I venture to think that Dr. Macfarlane has in his application of the term 'leaflet' distinctly exceeded the common and convenient use of that term.

F. O. BOWER, Glasgow.

NOTE ON ATTEMPTS TO INDUCE APOSPOROUS DEVELOPMENTS IN FERNS.—It is now known that in at least four distinct genera of Ferns growths of an oophytic nature may be produced directly from the sporophyte, without the intervention of spores: in all these cases the phenomenon of apospory appeared spontaneously, i. e. without any intentional exposure of the plants by man to peculiar circumstances. But the further fact that apospory had been artificially induced by Pringsheim and by Stahl in certain Mosses suggested the possibility that it might similarly be induced in Ferns. I accordingly made numerous cultures with this object in

[1] Phil. Trans. 1884, Part II, p. 611.

view. The first of these were made at Peradeniya, Ceylon, in 1885, and were continued for about two months: pieces of the fronds of *Polypodium aureum*, *Adiantum peruvianum*, *Angiopteris evecta*, and *Aneimia*, sp. were selected, with immature sori, and laid on damp soil; but they simply rotted, without any further development. From October, 1888, similar experiments have been made for me by Mr. Sherry in the Glasgow Botanic Garden, the subjects being selected from over twenty genera, and forty-six species and varieties: portions of fronds of various ages were laid, for periods up to six months, on and among *Sphagnum*, which was kept constantly moist, and at an equable temperature. The results have been, that in no single case has any outgrowth of an oophytic nature been observed, except such as could be traced in origin to spores which had not escaped from the sporangia.

It is well, I think, to record these unsuccessful attempts, partly because it may suggest to others to make similar experiments under different conditions, but chiefly because they point to this conclusion, that there is a marked disability on the part of Ferns to bridge over the limits of the two generations by other means than by the formation of spores: the phenomenon of apospory is then by no means a promiscuous one, occurring readily and often, but a rare process, which seems to appear spontaneously, under conditions not yet understood, and is not readily induced. These observations decidedly enhance the importance of those examples of aposporous growths which have hitherto been recorded.

F. O. BOWER, Glasgow.

A LILY DISEASE IN BERMUDA.—For several years a disease has been prevalent in the lily fields of Bermuda, and has seriously damaged the crop, which is there quite an important one. During the past two winters I have devoted a good deal of my time to the study of this disease, and by means of a long series of experiments, both in the fields and in the laboratory, I have been able to prove that a fungus growing upon the leaves and flowers of the plants is the cause of all the trouble. This fungus is similar in all points to that described by Professor Marshall Ward in a recent number of this journal[1] as having caused a Lily disease in England, and from a specimen sent to him he has identified it as the same.

[1] A Lily-disease, by H. Marshall Ward, Annals of Botany, vol. ii, No. xii, November 1888.

The lily attacked in Bermuda is not the same as that which suffers in England, but a dwarf variety of the *longiflorum*, the so-called *Lilium Harrisii*, while that attacked in England is the *Lilium candidum*. The environment required by the fungus, and its method of growth, are, however, the same in both cases. It flourishes only in warm moist weather, being readily checked either by cold or by dry heat. In the ordinary course of events the fungus-spores germinate upon the surface of the leaves or flowers, soon penetrating and ramifying through the tissues, until, the conditions continuing favorable, both flowers and foliage droop and rot away, leaving only the bare stalk.

A. L. KEAN,
Mass. Inst. of Technology, Boston, U.S.A.

THE ONION DISEASE IN BERMUDA.—In the Kew Bulletin, No. 10, Mr. A. E. Shipley published an account of the onion disease, of which he had made a careful study in Bermuda. He attributes the disease to the ravages of a parasite (*Peronospora Schleideniana*). More lately Mr. Kingo Miyabe, having worked with material sent from Bermuda, published in the ANNALS OF BOTANY[1] a paper on *Macrosporium parasiticum*. In the appendix of this latter article Prof. Farlow states that in making these investigations it was desired to show 'whether the *Macrosporium* was merely a fungus which had attacked plants previously suffering from *Peronospora*, as most botanists would suppose, or whether it might not of itself cause a disease of onions.' Whether this is so or not is most important both from an economic and from a scientific standpoint. Mr. Shipley does not, however, seem to consider that Mr. Miyabe's experiments on this subject are entirely conclusive[2].

It is not my intention to discuss this question, but only to say, that while in Bermuda in the winters of 1888 and 1889 I studied the disease, and my observations correspond with those of Mr. Shipley, who says that, though he examined many hundred diseased onions in all states of attack, he never saw one suffering from the black mildew (*Macrosporium*) which had not previously been attacked by the white (*Peronospora*). So that it would seem to me that whatever are the possibilities of *Macrosporium* growing as a parasite,

[1] No. ix, 1889. [2] Annals of Botany, No. x, 1889.

at least in the case of the Bermuda onions it does not appear to be the cause of the disease.

A. L. KEAN,
Mass. Institute of Technology, Boston, U.S.A.

A HYBRID DESMID.—In a gathering made on Dartmoor in August, 1889, I met with the first recorded instance of what seems to me the phenomenon of hybridism among Desmids. The accompanying figure (Fig. 4) represents the appearance of this organism, multiplied 200 diameters. It is clearly intermediate between *Euastrum crassum*, Ktz. and *E. humerosum*, Ralfs; the lower half corresponding closely to the typical form of the former of these species, the upper half to that of the latter. Of the normal forms of these species, *E. crassum* was one of the most abundant in the gathering, *E. humerosum* was only rarely seen. The suggestion no doubt presents itself, whether it may not be an abnormal form of one of these species. *Euastrum humerosum* is not, according to my observation, nor, I think, to those of others, a very variable species. *E. crassum* is, no doubt, subject to considerable variation. The var. *cornubiense* mihi (Journ. R. Microsc. Soc. 1887, Pl. IV. f. 18), presents a certain approach to the high shoulders characteristic of *E. humerosum*; and in several of De Wildeman's figures in his very careful account of the varieties of *E. crassum* (Observations sur quelques Desmidiées, Bull. R. Soc. Bot. Belg. 1888), the two semi-cells present notable inequalities. Several writers have also suggested that *E. humerosum* may be simply a variety of *E. crassum*. But, assuming that it is most convenient to regard the normal forms as distinct species, I think we have here considerable evidence of hybridity. The two half-cells are distinctly unequal in size, the lower or larger half measuring 90 μ in length, by 92·5 μ in breadth, the upper or smaller half 82·5 μ in length and breadth. The lower half has but a slightly diminishing diameter as far as the first and only deep indentation, in fact the normal form of *E. crassum*; while in the upper half there are, as in *E. humerosum*, first a shallow and then a much deeper indentation, the diameter narrowing rapidly towards the apex. It is interesting, however, to observe that the arrangement of the protuberances or inflations is

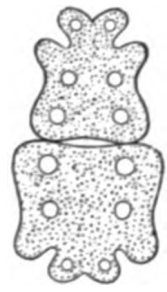

Fig. 4.

nearly alike on the two halves, and corresponds to that of *E. crassum* rather than of *humerosum*. Another difference, which is not represented in a front view, is that the lower is decidedly thicker than the upper half, but I was not able to obtain any exact measurements.

That hybridity should occur among the Desmidiaceae is not in itself surprising, several well-authenticated instances being on record in the allied Zygnemaceae. Professor Vines has pointed out to me that if this is a true instance of hybridity, it must be temporary in its character; since, if the individual were to reproduce itself in the ordinary way by fission, each half-cell would probably reproduce a half-cell like unto itself.

ALFRED W. BENNETT, London.

VAUCHERIA-GALLS.—The literature of the so-called 'galls' on various species of *Vaucheria* is not very extensive. Benkö gives a list of those who have observed them up to the date of his paper; but as this paper, which appeared in the 'Magy. Nov. Lapok.' vol. vi, 1882, p. 146, is probably not accessible to the readers of the ANNALS, I transcribe the list from the notice in the 'Botanisches Centralblatt,' vol. xiv, 1883, p. 1:—Vaucher 1803, Lyngbye 1819, Unger 1827 and 1834, Wimmer and Valentin 1833, Fürstin Friderike 1836, Morren 1839, Hofmeister and Cohn 1853, Kützing 1856, Magnus 1876, Wollny 1877 and 1878, Cornu and Balbiani 1874 and 1878, Benkö 1882. From this list are omitted the only two descriptions with which I am acquainted by English observers before that time, viz.:—by Sir J. E. Smith in 'English Botany,' 1st ed., vol. xxv, t. 1765, and Hassall, 'Freshwater Algae of Great Britain,' 1845, p. 56. The only description I have met with since Benkö's paper is by Lister, in the 'Proceedings of the Essex Field Club,' vol. iii, 1884. The earliest figures are those by Vaucher, 'Conferves d'eau douce,' 1803, t. iii, f. 8, and Smith, 'English Botany,' 1st ed., 1805, t. 1765; and these, though rough, are fairly accurate. I know of no figures later than these, except the very admirable ones in Balbiani's exhaustive account of the parasite in the 'Annales des Sciences Naturelles,' Zoologie, vol. vii, 1878, t. iv[1]; and the woodcuts in Lister's paper referred to above.

The species infested by the 'galls' is stated by Smith to be *Vaucheria sessilis*, by Hassall *V. racemosa*. Benkö gives the

[1] An abridgment, with the illustrations of Balbiani's paper, appears in the Journal of the Royal Microscopical Society for 1879.

following list of species on which they have been observed:—*V. racemosa*, *dichotoma*, *clavata*, *caespitosa*, *geminata*, *uncinata*, *terrestris*. Lister has also observed them on *V. aversa*, Hass. and *V. Dillwyni*, Ag. The animal (rotifer) which gives rise to them is described in the earlier papers as *Cyclops lupula*, Mull.; but Balbiani and others have identified it, in all the species examined, with *Notommata Werneckii*, Ehrb.

I append a figure (Fig. 5, × 200) of one of these 'galls' found on a *Vaucheria* growing on the surface of a wet rock at Buckfastleigh, Devon, in August 1889. Having no organs of fructification, the species could not be determined with certainty, but is probably *V. sessilis*, Vauch. The 'gall' is a vesicular appendage attached to the filament nearly at right angles; its length from five to six times, and its greatest breadth about twice that of the filament, from which it springs by an open neck about as wide as the filament. The protoplasmic contents of the filament and of the vesicle are in complete communication; and the latter is rich in chlorophyll, which however has retreated from the cell-wall, leaving a parietal space filled with granular colourless protoplasm. Within the chlorophyllous portion is seen the living animal, which feeds upon the protoplasm of the vesicle, but, according to Balbiani, not on the chlorophyll.

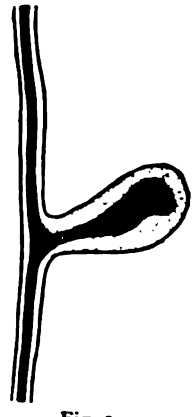

Fig. 5.

The 'galls' are described by several observers as frequently present in large numbers on the same filament; but they are certainly sometimes solitary. From the fact that the filaments attacked are never fertile, it has been suggested that they weaken the plant, and prevent its forming sexual organs; but Balbiani has clearly shown that the 'gall' is a lateral fertile branch which the parasite has entered at an early stage, prevented it from forming oogones and antherids, and cause it to swell to from four to five times its original size by hypertrophy, brought about probably by the action of a stimulating secretion, as in true galls. This is further confirmed by the horn-like protuberances with which they are frequently furnished; but these were not present in those observed by me. If this view of their formation is correct, they are not accurately described as galls—a term which should be

confined to special structures brought into existence entirely by the stimulation of the parasite. Their history may be compared, in its general features, to that of the 'bladder-plums' produced by the attacks of *Exoascus*.

ALFRED W. BENNETT, London.

ON THE STOMATA IN THE FRUIT OF IRIS PSEUDACORUS, LIN.—So many papers have been written on the development and structure of the stomata of plants that it might seem almost superfluous to contribute any further details to a subject on which our knowledge appears to be so complete. But the conditions which regulate the process of cell-division in a leaf (and it is in leaves that stomata have chiefly been studied) are not precisely similar to those which obtain in a growing fruit, and it is probably upon this fact that the peculiarities now to be described in some measure depend.

Whilst in leaves the division of the epidermal cells, so far at least as the production of stomata is concerned, ceases at a comparatively early stage, this is frequently not the case in growing fruits, and *Iris pseudacorus* presents a striking example of stomatal formation extending over a considerable period of time.

The epidermis of the ovary in a young bud consists of small, somewhat irregularly elongated cells from which the mother-cells of the stomata are cut off in the way described by Strasburger[1] for the leaf of this plant. The ovary does not however reach its full size until the bud is almost ready to expand, and if the epidermis be examined at this stage its cells clearly exhibit the properties of tissues still in a merismatic condition.

If the flower be fertilized the ovary swells, and rapidly increases in size, and this process is accompanied, not merely by growth and extension on the part of the epidermal cells, but also by a very considerable increase in their number. As this takes place, certain cells become clearly marked off from those which surround them, both on account of their much smaller size, and also by their richness in protoplasmic contents. These small cells are the potential mother-cells of a fresh series of stomata, and their development may be traced in all stages (Figs. 6–13). Not all, however, of these cells appear actually to give rise to stomata, for in fruits of an advanced age they may be detected in various stages of arrested development. When

[1] Ein Beitr. zur Entwickelungsgesch. d. Spaltöffnungen, Pringsh. Jahrb. Bd. V.

they do give rise to the secondary stomata, they behave in precisely the same way as the mother-cells of the primary series, but they never, apparently, attain to the same size as the latter, and are thus always easily distinguished from them. The epidermal cells which border on the new guard-cells frequently divide in such a way as to produce a resemblance to subsidiary cells, and this may also occur

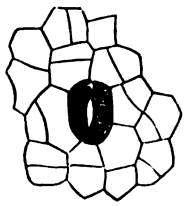

Fig. 6.

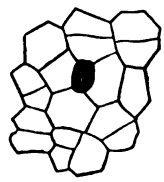

Fig. 7.

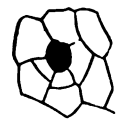

Fig. 8.

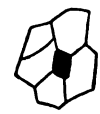

Fig. 9.

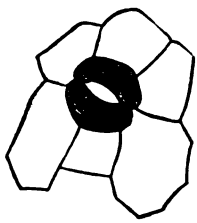

Fig. 10.

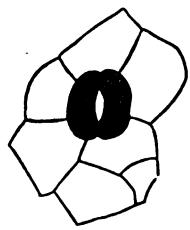

Fig. 11.

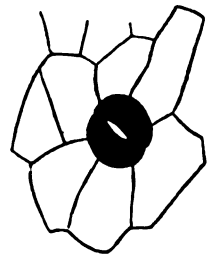

Fig. 12.

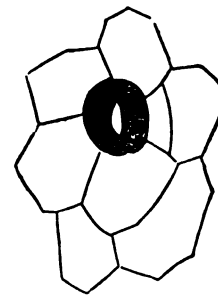

Fig. 13.

Fig. 6. Primary stoma in ovary of flower-bud. Figs. 7, 8. Younger stomata in same bud.

Fig. 9. Newly-formed stoma after withering of the flower.

Figs. 10–13. Primary stomata dividing in half-ripe fruits.

round the primary stomata, but in both cases the phenomenon is of irregular occurrence.

Meanwhile, besides mere increase in size, the guard-cells of the primary stomata are influenced, though indeed to a partial extent only, by the causes which lead to the renewed and active division in the rest of the epidermal cells. They also, in many cases, make feeble attempts to divide, but they exhibit considerable irregularity, both in the extent and in the manner of their division, as the Figures 5–8 clearly show, and it is very common to find that even the two

guard-cells of the same stoma do not behave alike. In some cases one, in others both, guard-cells contain two nuclei, but the cell-wall between them has failed to appear; and all transitions may be observed until each guard-cell is divided transversely into two cells, each of which contains a nucleus. I have never seen further division occurring, nor in any direction except transversely.

This peculiar behaviour of the guard-cells in the fruit seems to be confined to this species of *Iris*; I have frequently examined other species, but hitherto without success. In *Iris pseudacorus* it is of very common, but by no means of universal, occurrence, as I have failed to find it in certain specimens; still, as I believe there exists no mention of such a division of the guard-cells of stomata, this case seemed deserving of being put on record.

J. BRETLAND FARMER, Oxford.

POSTSCRIPT.—Since the above has been in type I have met, in W. P. Schimper's Recherches sur les mousses, 1848, Pl. VIII, Fig. 22, with a figure showing division of a guard-cell of a stoma in *Polytrichum commune*. In the text, however (p. 165), the author contents himself with a bare mention of the fact, without offering any explanation of it.

MYSTROPETALON THOMII, HARV.—The nearness of affinity of this genus of the Balanophoraceae to such a genus of the Santalaceae as *Myzodendron* suggested to me an examination of its ovules, to see if there was any indication of an elongation of the embryo-sac such as occurs in Loranthaceae and in Santalaceae. I was able, through the kindness of Mr. Jackson, to examine spirit-material of the plant in the museums of the Royal Gardens, Kew. The material gathered many years ago at the Cape of Good Hope by Dr. Harvey is, unfortunately, not in a condition to permit of a detailed microscopic examination, but is yet sufficiently well preserved to allow me to say that there is in *Mystropetalon* a secondary elongation of the embryo-sac at both synergidal and antipodal ends of such a nature as to bring about conditions for the nursing of the embryo similar to those found in *Myzodendron*. Probably examination of other Balanophoraceae would yield similar results. I am now waiting for fresh material of the plant, which Mr. Bolus is attempting to get from 'About Caledon Baths.'

T. JOHNSON, South Kensington.

Monograph of the Lemaneaceae of the United States.

BY

GEO. F. ATKINSON,

Professor of Biology, Alabama Polytechnic Institute, Auburn, Alabama, U.S.A.

With Plates VII, VIII and IX.

INTRODUCTORY [1].

THE investigations leading to the present Monograph of the Lemaneaceae of the United States were undertaken at the close of the month of December, 1884, and concluded in November, 1889. The research has been prolonged through nearly five years in order to repeat the work, both for the purpose of verifying the observations and to eliminate so far as possible any items of error.

The obscurity of some of the phases in the life-history of these plants; the difficulties attending the collection of material owing to their peculiar habitat and the rigors of winter during which time they pass through the greater part of their development; have deterred me from presenting the work for publication before at least the complete life-history and anatomy of the two natural groups to be found in the genus should have been examined in detail.

Sirodot [2] discovered the organs of reproduction and certain structural characters naturally differentiating the species of Lemaneaceae into two well-defined groups. These he

[1] The works referred to are enumerated in the Bibliography on p. 212.

[2] Étude sur les Algues d'eau douce de la Famille Lémanéacées, Ann. d. Sci. Nat. 5th Ser. Bot. xvi, 1872.

recognizes as of generic value. For one group he retained the name *Lemanea* Bory; to the other he gave the name *Sacheria*.

Ketel[1] recognizes these two natural groups, but considers them of subgeneric value only.

While the structural characters of the plants clearly show a natural division, the reproductive organs present only minor variations. The structural differences alone do not seem of sufficient value to warrant the acceptance of more than one genus. However, for convenience of study and determination, as well as for the suppression of great confusion of species which has always resulted from a merely superficial knowledge of the anatomy, it is well to emphasize the importance of this natural distinction into two groups. I shall therefore retain *Lemanea* Bory, emend. C. A. Agardh, for all the species at present known, and reduce *Lemanea* Sir'dt. and *Sacheria* Sir'dt. to subgeneric position.

The subject-matter of this work naturally groups itself into the following paragraphs:—

I. HABITAT.
II. MORPHOLOGY OF THE PLANT-PARTS.
III. DEVELOPMENT.
    1. *Germination of the Spores.*
    2. *Development of the Protonema.*
        A. *Prostrate (permanent) form.*
        B. *Chantransia-form.*
    3. *Development of the Sexual Shoot.*
    4. *Development of the Reproductive Organs.*
IV. FERTILIZATION AND DEVELOPMENT OF THE CARPOSPORES.
V. BRANCHING OF THE SEXUAL SHOOT.
VI. SYSTEMATIC PART.

The localities from which material has been obtained for

[1] Anat. Untersuchungen über *Lemanea*; Mittheilungen aus dem naturwissenschaftlichen Verein für Neuvorpommern und Rügen in Greifswald, 1886.

the prosecution of the work will be found in the systematic part under the different species.

I wish here to acknowledge my indebtedness to those who have so generously aided me in my investigations. To Dr. W. G. Farlow, of Harvard University, for the use of literature on the subject in the library, of a number of exsiccatae containing foreign species, for the use of the specimens of American Lemaneaceae in his herbarium, and for many words of valuable counsel during the completion of the work at his laboratory; to Dr. S. H. Vines, of Oxford, Eng., for valuable suggestions and criticisms; to my former teacher, Professor Wm. R. Dudley, of Cornell University, through whose advice and encouragement the work was first undertaken; and to Professor D. C. Eaton of Yale University, Professor J. A. Holmes of the University of N. C., Rev. Francis Wolle of Bethlehem, Pa., Dr. C. L. Anderson, Santa Cruz, Cal., Dr. Chas. Mohr, Mobile, Ala., Professor Edward S. Burgess, Washington, D. C., Mr. W. A. Setchell, of Harvard University, Mr. Isaac Holden, Bridgeport, Conn., Mr. Frank Collins, Malden, Mass., Miss Carter, of the Boston Society of Natural History, and Mr. J. M. Stedman, of Cornell University, either for the collection of material or for the use of herbarium-specimens.

I. Habitat.

The Lemaneaceae inhabit fresh-water streams, generally requiring the thorough aeration which is furnished in the turbulent waters at rapids, falls, mill-dams, etc. They are also dependent to a certain extent upon the depth of the water and force of the stream, being seldom, if ever, found in streams which do not have, at the rapids, a depth of water of one foot or more for the greater part of the year. In some small streams, where at most of the rapids the water is too shallow for their growth, occasionally the rocks are so situated as to confine the water to a narrow passage, permitting it to dash down with considerable force upon the rocks below.

Some very fine specimens have been found in such situations. On the other hand, no streams seem to be too large, provided there are places where currents of water pass forcibly against the surface of rocks. It is generally stated that they inhabit the water of cold mountain streams, but any of our streams distant from the mountains furnish excellent examples where the other conditions obtain.

The members of the subgenus *Sacheria* seem, in general, to require water more thoroughly agitated, while the members of the subgenus *Lemanea* will, in some cases, flourish where there is little agitation, provided a deep and fairly strong current bathes some obstruction in an otherwise quiet stream. In this respect there is, naturally, some variation in species.

The plants are generally attached to rocks, but are sometimes attached to woodwork in the streams.

The plants are usually collected during the summer months, when, in many cases, the specific characters are not discernible. Collections should be made at several periods during the year, generally in late autumn, midwinter, early spring and summer. Even then latitude and temperature of stream must be consulted, in connection with some specific peculiarities of the plants themselves, to yield really valuable specimens to the collector.

II. Morphology of the Plant-parts.

The carpospore produces the *Lemanea*-plant by a rather complex, indirect, mode of development[1]. In an annual cycle of the polymorphic oophyte there are three distinct successional forms. It will be well at the outset to state briefly these forms and characterize them.

1. *Prostrate form*[2]. The first of these is the prostrate (permanent) form. It lives from year to year, not only reproducing itself, but in the autumn developing the earliest

[1] It is not to be inferred that these forms represent a perfect 'alternation of generations.'

[2] Sirodot, Ann. d. Sci. Nat., loc. cit., 'tissu proembryoniforme;' Bornemann, loc. cit., 'Haftgewebe;' Wartmann, loc. cit., 'niederliegende Strahlen.'

specimens of the form next to be described. The prostrate form fixes the plant to the substratum. It is either cellular or confervoid. The cellular prostrate form is an irregular mass of polyhedral cells spread over the surfaces of rocks in the places where the plant grows. If a section is made through this tissue perpendicularly to the rock, the cells will be seen to appear like those represented in Fig. 5 *a'*, Fig. 8 *a* and *a'*, or Fig. 4 *a*. Sometimes rhizoids like Fig. 6 *b* are intermingled with the cellular tissue.

The confervoid prostrate form is a weft of slender confervoid filaments more or less compactly twisted and matted together; Fig 24 *a* represents a few of these filaments somewhat disentangled. Among the elements of the confervoid prostrate form there occur rarely polyhedral cells similar in form to those described for the cellular prostrate form.

2. *Chantransia*-form[1]. The second form in the life-history of the plant is *Chantransia*-like. It gives rise to a special branch, the sexual shoot. It is developed mainly from the prostrate form, as erect lateral shoots; rarely it is developed directly from the spores. Though it has a *Chantransia*-aspect it produces no gonidia. The branched filaments are composed of single series of elongated cells placed end to end. Figs. 6, 8, 10, 24, 26, represent the *Chantransia*-form. The endochrome gives to the *Chantransia*-form a yellowish-bluish or green color, in some species violet. Its period of development is from October to the first or middle of the winter months, sometimes fragments lingering until late spring.

The prostrate form, and *Chantransia*-form, constitute what is sometimes termed the vegetative stage[2] of the plant. It is the protonema, and bears a striking resemblance to the protonema of the Mosses.

3. *Sexual Shoot*[3]. The third and last form of the plant is

[1] Wartmann, loc. cit., 'aufrechte Strahlen;' Sirodot, Ann. d. Sci. Nat., loc. cit., 'Thalle;' Bornemann, loc. cit., 'Thallus.'

[2] Wartmann, loc. cit., 'Vorkeim;' Ketel, loc. cit., 'Vorkeim.'

[3] Wartmann, loc. cit., 'Fäden;' Sirodot, loc. cit., 'Filament fructifère;' Ketel, loc. cit., 'Thallus;' Bornemann, loc. cit., 'Fruchtkörper.'

the sexual shoot. These are the most conspicuous parts of the plant and those usually taken by collectors. They originate as special lateral shoots from the *Chantransia*-form. They begin their development late in autumn or early winter and reach maturity late in the following spring or early summer.

The most characteristic stage of the sexual shoot is during the period of fertilization, which occurs at a variable time from January to March. The time depends largely upon the temperature of the stream as determined by climatic conditions or altitude. They occur usually in dense circumscribed tufts or in extensive mats, covering sometimes several square feet of rock-surface. The individual sexual shoot is simple or very much branched, and rather stoutly filiform. At regular intervals there are plane or papillate enlargements, sometimes very prominent. At this stage they are of an olive-yellow, greenish, or violet color, and commonly from 2 cm. to 16 cm. long, and being flexible, lie in the direction of the current, or are arcuate. At the period of fertilization the enlargements can well be seen with the unaided eye; sometimes they are much more prominent at maturity and sometimes less so. Figs. 56 and 57 represent two sexual shoots, natural size.

If this simple description has enabled the reader to recognize the plant at this period of its development, the external characters which separate the family into two natural groups may be pointed out. To one familiar with these characters such a determination could usually be made at sight without the use of any magnifying power. A small hand-glass, however, will enable any one to recognize these characters at the time of fertilization.

I will select as a representative of the simpler group a widely distributed and very variable species, *Lemanea fucina* Bory, so named because of its resemblance to certain species of a filiform *Fucus*[1]. By examination with the hand-lens the enlargements will probably resemble one of those illustrated

[1] Bory, Ann. d. Mus., etc., loc. cit.

in Figs. 53, 54, 55, 56, which are varieties of this species. By referring to the explanation of the plates and the description of this species in the systematic part, the varietal names and habitats of these forms can be ascertained,

In the form represented by Fig. 55 the papillae are very prominent and the portion of the sexual shoot between them is nearly or quite cylindrical. There are no 'hard and fast' lines between these varietal forms, so one will be likely to find great variation in the number and form of the papillae and the shape of the portion of the sexual shoot between them, even in material from the same locality, though most of the forms can be grouped around one or another of these.

The summits of these papillae will appear, even with a small hand-glass, of a different structure from the other portions of the surface of the plant. The elements are very much finer in structure and often of a slightly different color. So where the papillae are not prominent above the surface of the plant, as in some forms, the spots which correspond to them in structure, and as we shall later see in function also, can easily be seen. The fine elements making up the surface structure of these spots are the male organs, or antheridia. Sometimes these papillae become so numerous or large that they may be confluent in a ring around the enlargement, as is shown in Fig. 53, but by far the greater number of them will be separate and distinct, so that by examining the whole length of the plant it will be easy to determine if the specimens belong to this natural group. The members of this group belong to Sirodot's[1] genus *Sacheria.*

If we now make a similar examination of a specimen of the other natural group the external differences will be manifested. The enlargements are not papillate, but are plane, rarely angular. Figs. 47–51 and 57 represent portions of the sexual shoot of several different species. The antheridia here, instead of being in definite patches, are almost always confluent into a more or less regular band around the middle of

[1] Ann. d. Sci. Nat., etc., loc. cit.

the enlargement. Sometimes near the base of the sexual shoot the band is interrupted, so that the antheridia are in spots, but they are not elevated on papillae, and by examining the entire length of the plant the bands in the middle and terminal region will be found almost universally complete[1]. For this group Sirodot retained the generic name *Lemanea.*

If in some cases an external examination fails to reveal satisfactory characters for the determination of the two subgenera, a microscopic examination of the internal structure will furnish the evidence.

The sexual shoot is hollow, or tubular, containing a system of delicate filaments, the apparatus of fructification, which will be described after explaining the structure of the walls that protect the internal organs and give strength to the plant.

Structure of the wall of the sexual shoot. The wall is more or less cartilaginous in nature and is composed of three different kinds of cells arranged in three layers. The medullary layer (inner layer) is composed of a single layer of comparatively large cells, 40 μ. to 70 μ. in diameter (Figs. 14 *f*, and 32). The cells vary from irregularly oblong to oval and spherical, are hyaline, possessing very little endochrome. The endochrome is arranged in small plates on the inner periphery of the cells. The intermediate layer is composed of somewhat smaller cells, polyhedral in form and containing a little more endochrome. The cortical layer is composed of prismatic cells, quite small, arranged parallel to each other and standing perpendicularly to the intermediate layer. The cells of the cortical layer are very rich in coloring matter. In some species, especially of the subgenus *Lemanea,* at maturity, the cortex is composed of two or three layers of cells (Figs. 41, *L. australis*, n. sp. and 46, *L. grandis*).

Fig. 32 represents a longitudinal section of the sexual shoot of *Lemanea australis* Atk. at the period of fertilization. It is sufficiently clear to show the three different layers with their

[1] One species described by Sirodot, Ann. d. Sci. Nat., loc. cit., *L. parvula*, belonging to this group, had the bands generally interrupted.

characteristic cells. The elements composing the medullary and intermediate layers show large spaces, while the cells of the cortical layer are compactly arranged. The cells excrete a mucilaginous substance which fills the intercellular spaces, surrounds the entire sexual shoot during its growth, and soon fills the interior after the cavity is formed.

The sexual shoot derives its nourishment first from the *Chantransia*-form from which it arises as a branch. It soon becomes independent by the development of rhizoids at its base, which form a dense tangled mass with the decreasing elements of the *Chantransia*-form. It must be examined while still quite young to observe its origin from the *Chantransia*-form. In Fig. 8 these slender hyaline rhizoids are illustrated. About the time of anthesis, or later, the cells of the medullary, and sometimes of the intermediate, layer develop confervoid filaments, which in some cases are very numerous on the interior of the sexual shoot.

Apparatus of fructification. The apparatus of fructification situated on the interior of the hollow sexual shoot consists of a central axis, ray-cells[1], and generative filaments[2], with the tie-cells which unite the generative filaments with the medullary layer.

The central axis extends the entire length of the cavity. It is composed of a single series of cells placed end to end. Fig. 11 represents a portion of a longitudinal section of a sexual shoot, a little more than half of the interval between two adjacent whorls of papillae; *a* is the central axis. It will be seen that the cell *a* articulates with the cell directly below it in the middle of an interval between two adjacent whorls of papillae. Just below this articulation there are four ray-cells branching perpendicularly from the central axis, in the form of a maltese cross: *x*, the generative filaments arise, from the

[1] Sirodot, Ann. d. Sci. Nat., loc. cit., 'ramification cruciforme;' Ketel, loc. cit., 'Stutzzellen.'

[2] Sirodot, loc. cit., 'tubes latéraux,' or 'tubes placentales;' Ketel, loc. cit., 'wandstandige Zellreihen.' I have termed them generative filaments because they give origin to the reproductive organs.

ends of the ray-cells and extend both up and down to the bases of the papillae. Fig. 11 is from *Lemanea* (*Sacheria*) *fucina*. Fig. 32 represents a part of a longitudinal section of the sexual shoot of a species of the subgenus *Lemanea* (*L. australis* Atk.): *a* is the central axis, *b b' b'' b'''* the ray-cells; *d* and *d'* a descending and ascending generative filament. The descending one ends, as can be seen in the figure, at the base of the antheridia *g*. In Figs. 32 and 11 *e e e* are the female organs, procarps. In Fig. 32 they arise from the generative filaments near the middle of the interval between two adjacent antherid-bands, and in Fig. 11 they arise from the generative filaments near the antherid-papillae.

In order to be concise in speaking of the different portions of the sexual shoot and save the circumlocution which I have used in speaking of the 'interval' and 'whorls of papillae,' I will use definite terms for the alternating zones.

Since the terms 'node' and 'internode' do not in the usual acceptance of those terms seem proper, and because I wish to use terms which have some appropriate significance of the function of the alternating zones, I shall use the term antherid-zone for that portion of the sexual shoot which includes the antherid-band or antherid-papillae as the case may be; and the term procarp-zone for the alternating zones, or that portion which lies between two adjacent antherid-zones. Then since a procarp-zone with half of each adjacent antherid-zone is a sexually complete segment of the sexual shoot, I shall use the term sexual segment, or segment, to indicate that.

While in general the structure of the apparatus of fructification is similar in both subgenera, its elaboration in the subgenus *Lemanea* is more complex, and each merits consideration in detail. In the subgenus *Sacheria* the central axis is always naked. The ray-cells are T-shaped or L-shaped, one end of the cell being joined to the central axis, the two other ends forming the beginnings respectively of the ascending and descending generative filaments and closely applied to the medullary layer. Each ray-cell is 'tied' to the medullary

layer by pyriform or boot-shaped cells, one on each side placed near the ends. The generative filaments are also closely applied to the wall throughout their entire length. In each sexual segment there are four descending filaments, corresponding to the descending ends of the ray-cells; and six ascending, alternate ascending ends of the ray-cells branching and forming two ascending generative filaments. Near the antherid-zone the cells are shorter and greater in diameter. Here they also branch, and the terminal cells of the branches are distributed to the bases of the papillae. See Figs. 11 and 12 for arrangement of generative filaments and shape of the cells.

In the subgenus *Lemanea* the central axis is at first naked, but later becomes entirely covered by slender filaments, which arise from the proximal ends of the ray-cells and spirally surround it (see Fig. 32). The ray-cells do not reach the medullary layer of the wall. They are simple cells, usually clavate, the smaller end joined to the central axis. The distal end is not applied to the wall, but is supported by another clavate or pyriform cell. The shape and relations of the ray-cell and tie-cell can well be seen in Fig. 32. These tie-cells are connected where they meet with the medullary layer, by three or four pyriform cells. The generative filaments arise from the distal ends of the ray-cells, and are also separate from the wall, being supported by pyriform tie-cells, except at the antherid-zone, where they come in contact with the wall. In their disposition they exceed in number those of the subgenus *Sacheria*. Two oppositely situated ray-cells give rise each to four generative filaments, two ascending and two descending. One of the ascending generative filaments nearly always branches after the first cell, making three ascending filaments for two ray-cells. The other two oppositely situated ray-cells bear each three generative filaments, one ascending and two descending. Thus at the point of origin of the generative filaments from the ray-cells there are six ascending and eight descending, the ascending becoming eight by the branching of two of the first cells.

After fertilization, the carpospores are developed from a whorl of ooblastema-filaments which grow from the terminal cell (carpogenic cell) of the procarp and form large clusters on the interior of the sexual shoot. Figs. 58 and 60 represent them in *L.* (*Sacheria*) *fucina* Bory, var. *mamillosa* and *L.* (*Sacheria*) *fluviatilis* Ag. Fig. 59 represents them in *L. australis* Atk. Figs. 18, 43 and 46 represent carpospores more highly magnified.

Having familiarized ourselves with the forms of the *Lemanea*-plant, and its structure, it will now be in order to take up the study of the development from the carpospores to the maturity of the sexual shoot.

III. Development.

1. *Germination of the Carpospores.* The germination of the carpospores can be studied very easily in the autumn, by collecting the remains of old sexual shoots of *Lemanea* and examining them in the material which is in a fair progress of disintegration. The time will vary to some extent for the different species, and different temperatures, due either to seasonal climatic variation, latitude, or temperature of the stream. I have studied the germination of the carpospores in two species, one species of the subgenus *Sacheria*, and one of the subgenus *Lemanea*.

The carpospore is oval, elliptical, or oblong, more or less irregular in outline, varying to a limited extent in shape and size in some species, though this character alone cannot be relied on for the distinction of species. The protoplasm is highly granular, somewhat yellowish, or bluish-green when recently matured. The carpospore possesses a distinct central nucleus and nucleolus.

The germ-tube begins by a protrusion of the wall at a point. Fig. 2 represents the beginning stage in the subgenus *Sacheria* (*Lemanea fucina* Bory). Reagents were applied before making the drawing to bring out more clearly the relation of the spore-wall. Fig. 3 represents a farther

development, the nucleus has divided, one part remaining in the spore, the other going into the germ-tube. Transverse fission soon takes place and a short oblong cell is formed. The germ-tube continues to elongate and produces a row of cells which soon branch as represented by the short cells at *a*, Fig. 4. Sometimes the germ-tube is proportionately more slender, as in Fig. 1, and grows more rapidly by extension in a longitudinal direction, producing confervoid elements of elongated narrow cells. The production of confervoid elements in the germination of the spores of the subgenus *Sacheria* is much less frequent than the development of the short cells represented in Fig. 4. It is quite probable that in some cases these confervoid elements may be quite numerous, but on reaching the substratum they soon develop the cellular form.

Just the opposite condition of things obtains in the subgenus *Lemanea*, where the confervoid elements predominate. There is a direct relationship between these facts and the nature of the prostrate form of the two subgenera. The short, polyhedral cells predominate in the subgenus *Sacheria*, and the confervoid elements in the subgenus *Lemanea*. Rarely the *Chantransia*-form may arise directly from the spore in the subgenus *Sacheria* about the same time that the germ-tube arises which produces the prostrate form. I have observed it in a few cases. In the subgenus *Lemanea* it is of quite common occurrence. In germination, the spore of this subgenus may develop one or two germ-tubes. Where there are two from a single spore, they generally represent two different kinds of the elements which make up the protonema. One forms a confervoid filament, an element of the prostrate form. This is produced even when a germ-tube of another character is put out from the spore. The second kind of germ-tube is an element of the *Chantransia*-form. While the second germ-tube is not so general as the first, it is quite common. It usually forms later than the confervoid germ-tube, after a few cells are developed, but it may precede it, as I have observed in quite a number of instances.

When the germ-tube is to produce the confervoid prostrate form, the point of origin from the spore becomes less rich in coloring matter, more hyaline and finally granular, partaking more of the nature of the confervoid element. When it is two or several spore-diameters long, it is separated from the spore by a transverse septum. The confervoid elements are slender compared with the elements of the *Chantransia*-form in some species, as *Lemanea australis*, while in some species, *L. annulata* for example, they are more nearly the same diameter. The cells are usually very long, unless the germ-tube meets with considerable resistance by the compactness of the surrounding elements. The second germ-tube, when it develops, is easily distinguished, even in the incipient stages, from the germ-tube forming the prostrate form. The arch of the spore-wall at the point of origin is perceptibly broader. The endochromic contents are richer at this point than in the other parts of the spore. When the germ-tube is a spore-diameter, or little more, in length, it assumes the characteristic form and coloring of an actively growing cell of the *Chantransia*-form. The endochromic contents are flocculent and highly colored. It is also separated from the spore by a septum. For several cells from the origin of an axis, the cells in *Lemanea australis* n. sp. increase in diameter, as shown in Fig. 21. Figs. 19, 20, 21, 22, represent different stages in the germination of the spores of *Lemanea australis*. These were drawn from living specimens. In Fig. 19 the spore is producing a confervoid element. Fig. 20 represents a little farther development of another one. Here a germ-tube forming a primary axis of the *Chantransia*-form has arisen directly from the spore. In Fig. 21 the primary axis of the *Chantransia*-form developed before the rhizoic element.

In making collections of the *Lemanea* during late autumn and through the winter, it is a very usual thing to find sexual shoots, especially of the more rigid cartilaginous species, of the previous year, very little disintegrated; the spores within in all stages of germination; the elements of the *Chantransia*-form growing through the walls in great profusion, and

sexual shoots of different sizes growing from these, giving the appearance of a profusely branched specimen. In such specimens I have found spores germinating as late in the season as March. The conditions under which germination took place in the species studied by myself were normal. The specimens of *L. fucina* were from Bolan's and Morgan's Creek, Chapel Hill, N. C., and the specimens of *L. australis* were from Morgan's Creek, Chapel Hill, N. C., and the Broad river, Columbia, S. C. The streams during the autumn and early winter were not at any time during the period below their normal depth, and part of the time were subject to floods.

Vaucher[1] observed the phenomenon I have described as a result of germination of the spores yet within the sexual shoot in *Lemanea fluviatilis* Ag., at first considering it a means of reproduction by budding. By later investigations he found it was a development from the spores still within the sexual shoot. He was the first to observe the germination of the spores, though he erred in thinking the germ-tube developed directly into new sexual shoots.

Wartmann[2] next studied the germination of the spores in *Lemanea annulata* Kütz[3]. From his figures it appears that the germ-tube produces principally confervoid elements, which we find to predominate in the subgenus *Lemanea,* in the prostrate form. He describes and illustrates the development from the rhizoids of enlarged cells, sometimes several united into a short filament, which seems to be characteristic of this species, especially the development of enlarged cells at the base of the axes of the *Chantransia*-form.

Sirodot[4] did not observe the germination of the spores, and thought what Vaucher interpreted to be young sexual shoots

[1] Histoire d. Conferves d'eau douce, pp. 91–95, 1805.

[2] Beiträge zur Anatomie und Entwicklungsgeschichte der Algengattung *Lemanea*, pp. 11–13, 1854.

[3] The species which was made the subject of his Inaugural Dissertation he called *L. fluviatilis*, but it clearly belongs to the subgenus *Lemanea.*

[4] Ann. d. Sci. Nat., loc. cit., p. 52, 1872.

growing from old ones, to be a parasitic *Chantransia*, which is very common sometimes on all *Lemaneaceae*.

Bornemann [1] observed the germination of the spores in a species of the subgenus *Sacheria*. The germ-tube, according to his account, produces cellular elements, thus agreeing with my own observation in this subgenus.

2. *Development of the Protonema.* A. *Prostrate form.* Thus far the study of the prostrate form and its development from the spores has furnished us with certain characters more or less common for each subgenus. There yet remains a study of its growth and development from other sources than from the spores.

Subgenus Sacheria. The cellular prostrate form characteristic of this subgenus is multiplied in one way by growth and budding of its own elements. It is also developed from the *Chantransia*-form in the following ways. After the *Chantransia*-form is well under growth, its basal cells develop slender rhizoids from the side of their proximal end. These upon reaching the substratum, or encountering some resistance, or probably in many cases in the absence of either alternative, begin to bud off short cells as branches from the terminal cell. Each one of these short cells begins to bud in several directions and produces other short oval cells. Finally, the pressure of the mass renders them polyhedral. Fig. 8 *a* represents clusters of these cells developed from rhizoids which have arisen from a short fertile branch *c* of the main axis *e* of the *Chantransia*-form. The rhizoid *b* coming from the first cell of the branch *c* has grown downward and developed serially three elongated cells. The first cell is quite slender; the second one is larger at the lower end, and the third one is considerably shorter. From the side of the last cell three of the characteristic cells have grown, and one from the end. Each of these cells now grows and by budding produces other similar cells, sometimes two or three, so that a firm mass of cellular tissue is developed at the end of the rhizoid. The

[1] Beiträge z. Kenntniss d. Lemaneaceen, p. 4, 1887.

rhizoid *b'* has, from a cell of the *Chantransia*-form, developed a series of cells that are a very little longer in comparison. Upon the upper surface of several of the cells a^1 protrusions of the wall appear. These protrusions are the beginnings of the main axes of new members of the *Chantransia*-form.

Subgenus Lemanea. The confervoid prostrate form of the subgenus *Lemanea* multiplies by the branching of the filaments composing the weft, and also by the development of rhizoids from the basal cells of the *Chantransia*-form as in the subgenus *Sacheria*, except that the rhizoids rarely produce cellular tissue, but branch in the same manner as the elements of the weft. The branches arise from the side of the end toward the direction of growth. See Figs. 23, 25, and 26. In Fig. 26 the rhizoid *a* has arisen high up on the branch of the *Chantransia*-form, but this took place because the *Chantransia*-form was crowded in the tuft.

In point of origin we might speak of a primary prostrate form and a secondary prostrate form, but in point of time there is no such division. The primary prostrate form would of course be that which is developed from the spores and increases by multiplication of its own elements; the secondary prostrate form would then be that which is developed from the rhizoids that grow out from the base of the *Chantransia*-form. But the portion of the prostrate form which has survived the summer produces the first increase of its elements at the same time that the first elements of the *Chantransia*-form are developed as erect lateral shoots. The basal cells of this new *Chantransia*-form soon produce new elements of the prostrate form. A little later the spores germinate and produce in point of origin primary elements, and so on. So that in point of time the primary and secondary elements are practically the same, as indeed we find them to be morphologically and functionally [1].

[1] Bornemann, loc. cit., pp. 6, 13, speaks of a 'primäres Haftgewebe' developed from the spore, and a 'secundäres Haftgewebe' developed from the rhizoids of the sexual shoot. He evidently entirely overlooked the development of the prostrate form from the *Chantransia*-form, which plays so important a part in the extension

It is in this way, by the development of the prostrate form from the rhizoids of the *Chantransia*-form, and new elements of the *Chantransia*-form in succession from this, with the process repeated successively for several weeks, that the extensive mats are produced covering the rocks where the social *Lemanea*-plants are found.

B. *Chantransia-form.* The origin of the *Chantransia*-form has already been noted; its growth and special characteristics remain to be noticed. In the subgenus *Sacheria* it is much smaller than in the subgenus *Lemanea*, in length ranging about 2 mm. or less, while the diameter of the cells is less, ranging from 15 μ to 30 μ. The cells are of nearly the same diameter throughout the length of the filament. In the growing cells the endochrome is first flocculent, then granular, and finally becomes arranged in plates along the inner periphery of the cells. In many cases the plates of endochrome are in close contact and some of them fused. Fig. 8 represents the arrangement of the endochrome. The endochromic-plates break down very easily, especially in the subgenus *Sacheria*, and it is necessary to have fresh material, and examine it soon after collection, in pure water.

In *Lemanea australis* the *Chantransia*-form at its origin is about 30 μ in diameter. As it increases in length it also increases in diameter. See Fig. 21. At a distance of four to five cells from the point of origin it is nearly of the normal diameter. The diameter of well-developed filaments ranges from 50 μ to 120 μ. The terminal, growing, cell is elongate oval, gradually becoming cylindrical or oblong, or in some cases broadly oval. The endochromic contents of the growing cell are very flocculent, more dense at the distal end and sides, usually with an irregular hyaline space near the centre. It is of a bluish-green color. As the cell becomes older the

of the tufts. It is quite likely that some of the rhizoids from lower primary groups of cells, where the sexual shoot is sterile and no cortex is developed, take part in multiplying the protonema, for they arise from cells of the sexual shoot which correspond to the generative filaments; but that rhizoids develop from cortical cells and then produce protonema is highly improbable.

endochrome becomes more finely granular, of a yellowish-green color, and is at last collected into irregularly shaped plates distributed unevenly over the peripheral portion of the interior of the cell. In some cases the plates are elongated and arranged in imperfect spiral rows in some of the cells. Such a disposition of the endochrome probably led Thwaites[1] to state that it was arranged spirally. Fig. 27 represents the arrangement of the plates, and the condition of an actively growing terminal cell of a branch.

After the development of the main axis of the *Chantransia*-form to several cells, primary branches arise from the proximal cells, Fig. 23. The distance of these primary branches from the base of the main axis is dependent upon its freedom. If crowded, they are at a greater distance. The branches of the *Chantransia*-form always arise from the side of the distal end of a cell.

In some species of the subgenus *Lemanea*, *L. annulata* Kütz. for example, the cells are of about the same diameter throughout, the filaments being much more slender than in *L. australis* Atk., but not so slender as in the subgenus *Sacheria*. In the subgenus *Lemanea* the filaments range from 3 mm. to 4 mm. in length. It usually persists around the cluster of sexual shoots and in sterile mats, throughout the winter, disappearing almost altogether in the spring, while in the subgenus *Sacheria* it is very fugacious, usually disappearing entirely quite early in the winter. Fig. 28 *a* is a rhizoid developed from the *Chantransia*-form; *b* is a short fertile axis of the *Chantransia*-form arising from the rhizoid and producing at its distal end a young sexual shoot *c*, and at the side a branch of the *Chantransia*-form. Fig. 22 represents a spore *a* soon after germination with an axis of the *Chantransia*-form growing directly from it *d*, and two rhizoids *b b*, also growing from the spore, which in turn are producing young axes of the *Chantransia*-form *c c*.

Thwaites[2] first fully described and figured a member of the *Chantransia*-form and its relation to the young sexual shoot.

[1] Loc. cit. [2] Loc. cit.

Wartmann[1] a little later described its development.

Sirodot[2] fully described the *Chantransia*-form ('thalle')[3], of several species, noted some which had been described and catalogued as species of *Chantransia*, and noted also the differences between the real Chantransiae and the *Chantransia*-form of the Lemaneaceae.

This phenomenon of a polymorphic protonema in the oophyte of *Lemanea* obtains in some other algae as well as in some of the Muscineae. In the oophyte of *Batrachospermum* Sirodot[4] has shown, and the author has demonstrated in the case of one of the American species[5], that in one series the carpospore develops a prostrate cellular permanent form of the protonema. This gives rise to the *Chantransia*-form which is a real *Chantransia*-plant and not only bears gonidia, but gives rise as well to the sexual *Batrachospermum*-plant. The protonema is increased not only by multiplication of the cellular prostrate form, and from rhizoids at the base of the *Chantransia*-form, but in addition is multiplied directly from the gonidia of the *Chantransia*-form.

In the Muscineae polymorphism of the protonema is common in such genera as *Mnium*, *Bryum*, *Barbula*, etc., where a secondary protonema (erect form) may be produced from the rhizoids by turning them up and keeping them in a moist condition for a few days. The rhizoids are morphologically comparable to the prostrate form of the protonema of *Lemanea*, not so much because they are prostrate, but because in many species[6] (of *Phascum*, *Funaria*, *Pottia*) they are the permanent form, and render the plants 'virtually perennial' by the aid of their rhizoids: the plants disappear entirely from the surface of the ground after they have

[1] Loc. cit.

[2] Ann. d. Sci. Nat., etc., 1872, Comptes Rend., 1873, and Les Batrachospermes, 1884, loc. cit.

[3] Loc. cit.

[4] Sirodot, Les Batrachospermes, Paris, 1884; Observations sur le Dével. d. Alg. d'eau douce, comp. le genre Batrachospermum, Bull. d. l. Soc. bot. d. France, xxii. 1875.

[5] Manuscript notes.

[6] Goebel, Outlines of Class. and Special Morph. of Plants.

ripened their spores, till the following autumn, when the mat of rhizoids again puts out new protonemal filaments, on which new moss-stems arise.'

In the Characeae, on the other hand, the protonema is simple; the rhizoids do not become changed into protonemal filaments but function as organs of attachment and for gaining nutriment.

3. *Development of the Sexual Shoot.* The special lateral shoot of the *Chantransia*-form, which is the sexual shoot, arises either from the basal cells or at a variable height. It can at once be distinguished from a normal branch of the *Chantransia*-form by the greater transverse diameter of its cells and their shorter axis (Figs. 6, 10, 28, *c*). The endochrome is darker in color, usually, in fresh specimens, and evenly distributed. The nucleus is usually very distinct. The cells are of two forms. The apical cell is convex at the distal end. In the subgenus *Sacheria* it is usually elongated in the direction of the longitudinal axis; in *Lemanea* it is quite short and shaped something like a 'half-moon.' Figs. 6 and 7 from *L.* (*Sacheria*) *fucina*, and Figs. 23, 28, and 29, from *L. australis*, represent the form of the apical and primary mother-cells. Each primary cell (Fig. 29 *b*) develops, by a process of centrifugal growth and peripheral and radial fission, into a perfect sexual segment. As the proximal end of the sexual shoot is always imperfectly developed it will be necessary to study the growth of a cell some distance from the base. The course of development might be anticipated as follows. The primary cell develops a whorl of four perpendicular branches, the bases of which cover at first the entire peripheral surface of the axis. The central axis now elongates rapidly downward: each ray elongates perpendicularly to the axis at the same time that its outer end divides into 3 to 5 cells, as the case may be, outlining the beginnings of the ascending and descending generative filaments and the tie-cells of the ray. Terminal growth of the cells just outlined for the generative filaments takes place rapidly, and extends up and down parallel with the central axis to form other cells of the generative filaments,

while peripheral growth forming the tie-cells proceeds more slowly and the cells are shorter and broader. Terminal and peripheral growth now proceed in like manner, the terminations of the ascending and descending generative filaments of adjacent segments of the sexual shoot remaining in contact; the tie-cells produce peripherally two to three cells of the medullary layer; these in turn produce in the same manner three to several cells of the intermediate layer, and these in like manner three to several cells of the cortex. While the cells of the medullary layer are forming they increase rapidly in size, and the edges of the corymbose branching of the four rays remain in contact a short distance from the axis, and a hollow tube is the result.

In detail the process varies for each subgenus and is as follows. The centrifugal growth of the primary cell proceeds for a time, when fission takes place and five daughter-cells result. The line of fission proceeds in such a manner as to give four concave faces to the peripheral contour of the central axis, and to make the four peripheral cells of unequal size (Fig. 30, cross section). Two opposite cells (*a*, *a'*) are larger than the other two opposite cells (*b*, *b'*). The outline of the four cells is somewhat trapezoidal, the larger cells have the broader end distal, and the smaller ones, proximal. Each of these cells is a mother-cell of a ray-cell and of one or two ascending and descending generative filaments.

Subgenus *Sacheria*. The two larger cells each produce one descending and two ascending generative filaments, and one ray-cell. Usually the first line of fission in any one of the cells is transverse and starts about two-fifths the way from the distal end on the outer surface and runs obliquely distal toward the central axis. After growth proceeds for a short time, the second line of fission, usually transverse, starts about the middle of the proximal cell on the outer surface and runs obliquely proximal toward the central axis. Sometimes this last line of fission is preceded by longitudinal fission of the first cell, so that the two ascending generative filaments are marked off before the descending one is differentiated from

the ray-cell (Fig. 7 *e*); at other times the descending generative filament is marked off first, or at the same time. Again, an oblique line of fission may first mark off one of the ascending generative filaments. There is no regular succession which is invariable, but the fission finally results in the four daughter-cells (Fig. 7 *g*, the group of cells at the right).

The ray-cell now elongates perpendicularly to the central axis, and the outer end, by peripheral fission, produces tie-cells, and by growth in the direction of the generative filaments forms the T- or L-cell. Each primary cell of the generative filaments, by peripheral and radial fission, produces the tie-cells, and by longitudinal growth and transverse fission produces another cell of the generative filament. This process is repeated together with the branching of the generative filaments until the antherid-zone is reached. An examination of Fig. 7 will show how the several first steps of the process proceed. The young sexual shoot, treated with potassium hydrate and then stained with eosin, contracts the young sexual segments and the product of fission of the four original peripheral cells into well-defined groups.

Subgenus *Lemanea.* Upon the character of fission of the mother-cells of the ray-cells and generative filaments depends the presence or absence of a tie-cell, which connects the ray-cell directly with the wall. The absence of this tie-cell usually occurs at the ray-cell which bears only one ascending and two descending generative filaments. The smaller cell (Fig. 29 *c*, the middle cell) is the mother-cell of these. It usually divides first into four cells in such a manner as to leave an inner pyramidal cell with a broad base resting against the cell of the central axis, and the apex short of the periphery of the mother-cell. The remaining cells are the primary cells of the one ascending and two descending generative filaments. (See Fig. 29 *m*, the central group of cells; the ray-cell cannot be seen in the illustration.) The ray-cell now merely elongates: it does not divide again, so that no tie-cell connects it directly with the wall. The larger mother-cell usually divides into five daughter-cells in such a manner as to leave a middle cell shaped

like the frustrum of a pyramid, its broad base resting against the central axis, its smaller end reaching to the peripheral surface of the mother-cell; the other four cells are the primary cells of the two ascending and two descending generative filaments, Fig. 29 *f*, the central group of cells; here the lower one has not yet divided longitudinally into the two generative filaments. The ray-cell here not only elongates but divides by transverse fission to produce the tie-cell which connects it directly with the wall. The tie-cells in this subgenus are very much elongated, so that the generative filaments are separated from the wall. Very early in the development of the sexual shoot, from the underside of the bases of the ray-cells, in the subgenus *Lemanea*, two or three articulated filaments of long slender cells grow out, branch, and run spirally downward around the central axis (see Fig. 32 *c*). When the sexual shoot is mature in this species (*L. australis*), and some others, the central axis is entirely hidden by a compact mass of these filaments.

The centrifugal development of a primary cell of the young sexual shoot is farther illustrated in the longitudinal section represented in Fig. 31.

The farther development of the walls in both subgenera is as follows. The tie-cells by peripheral and radial fission produce the cells of the medullary layer; the cells of the medullary layer by a corresponding fission produce the cells of the intermediate layer, and these in turn produce the cells of the cortical layer. In the development of each of these layers of the wall, as the periphery of the wall is constantly increasing in superficial extent, and as the cells of each layer are smaller than those from which they arise, it will be seen that each cell of the medullary layer and intermediate layer produce respectively a group of several cells[1].

[1] Ketel says (Anat. Untersuch. über *Lemanea*, p. 25, 1886), 'Weiterhin wiederholen dann die zulezt entstehenden Aussenzellen denselben Theilungsvorgang und theilen sich ebenfalls in eine innere und 2–3 "äussere Zellen."' He represents in Fig. 3 a side-view of the cells growing from a 'Verbindungszelle.' He has not given credit for a sufficient number of cells, since the branching of a

In the sexual shoots of *L. australis*, *L. nodosa*, *L. grandis*, and some others, especially of the subgenus *Lemanea*, the cortical layer continues to grow until two or three layers of these cells are produced (see Figs. 41 and 46), each primary cell of the cortex producing serially a row of two or three short cells.

As soon as the cells of the medullary layer are differentiated from the tie-cells, their radial faces being in contact, they increase in size very rapidly, thus exerting a mutual pressure which carries them together with the generative filaments away from the central axis. As the branching of the generative filaments is more profuse in the region of the antherid-zone, the medullary cells are consequently more numerous, and the pressure here produces a farther movement of the wall from the central axis, and the 'papillae' or enlargements appear. The central axis loses the concave faces which it first possessed and becomes cylindrical.

In the progressive development of the layers the greater portion of the endochrome lies in a peripheral plane of the sexual shoot, so that at last the cortex is more highly colored than the interior cells.

It will be remembered that, though each cell of the central axis corresponds originally in position to the axis of a primary cell of the young sexual shoot, in the mature sexual segment it articulates with the one above and below in the middle of the segment, and that the ray-cells are attached near the distal end of each cell. In the development of the primary cell, the axis elongates by growth chiefly toward the proximal end of the sexual shoot, so that its proximal end outgrows the descending generative filaments and reaches down into the segment directly below (Fig. 7 *i*).

Very rarely there are variations from the normal arrangement of four descending and six ascending generative filaments in the subgenus *Sacheria* until near the antherid-zones,

tie-cell results in a group of cells in the form of an inverted cone, the base of which is made up of the cortex. Each cell of the medullary and intermediate layers produces more than 2-3 outer cells.

where by a more or less free branching the number becomes quite variable. Since the branching of the generative filaments bears an important relation to their function, and to the variation of species, I have examined it in detail.

Subgenus *Sacheria*. The period of fertilization is the most favorable for determining the branching of the generative filaments, and fresh material should be used. A longitudinal section of a sexual segment should be made and placed, concavities upward, on a glass slide, and mounted in water. Protected by a cover-glass the branching can be studied with a high power. If the sexual shoot is of the right age the walls will be translucent, and the demonstration is easy. For about two-thirds of the distance between the ray-cells and the adjacent antherid-zones, the generative filaments are quite regularly six above and four below; but beyond this point a more or less free branching occurs. The amount of this branching is dependent upon the greater or less growth in size attained by the sexual shoot, and varies in individual plants collected in the same place. Fig. 11 shows the formation of additional short generative filaments. This is only a mild case. I have found a greater number both above and below[1].

Subgenus *Lemanea*. Beside the normal number of generative filaments, redundant branches arise, but those which arise near the ray-cells rarely reach the antherid-zone. This branching is more profuse in the more robust specimens of the larger species. Fig. 44 represents one half of a segment of well-developed portions of *Lemanea australis*: *a* is the central axis, b^1 and b^2 are the ray-cells of the removed half, *b* and b^3 are the ray-cells connected with the preparation.

[1] Wartmann (loc. cit.) in the main correctly observed the arrangement of the normal number of generative filaments in the species studied by him; so has Bornemann (loc cit.), but he incorrectly translates Sirodot, and charges him with an error. Sirodot (loc. cit.) states the normal number of six ascending and four descending correctly, but, by making cross sections of the sexual shoot near the antherid-zone, did not interpret the branching correctly. Ketel (loc. cit.) also describes correctly the normal number of generative filaments, but the branching of the generative filaments in the region of the antherid-zone in the subgenus *Sacheria* and the redundant branching in the subgenus *Lemanea* seem to have escaped close observation.

The section is fortunate in presenting a ray b^3 which bears four generative filaments e e^1 e^2 and e^3, and a tie-cell c; the other ray-cell b bears three generative filaments e^4 ascending and e^5 e^6 descending, and no tie-cell. In this half of the sexual segment the normal number of generative filaments is three ascending at their origin on the ray-cells e^2 e^3 and e^4, and four descending, e e^1 e^5 and e^6; but the normal number of ascending filaments becomes four by the branching of the first cell e^2, forming h and h^1; g g^1 g^2 are redundant ones from the normal one e^4, formed by the growth of its primary tie-cell on that side; f is a redundant one arising from a descending one, e^6, by an extension of the middle tie-cell of the first cell of the filament. Nearly all of the primary tie-cells possess secondary tie-cells, which connect them with the wall. In many cases the secondary tie-cell, which lies in the direction of the antherid-zone, is continued into a short redundant filament. Many of these redundant generative filaments function as normal ones by producing antheridia. On e, k^1 is the first tie-cell which forms a fertile redundant generative filament. The next one arises from the next cell on the opposite side, k^2; k^5 the next one on the opposite side of the next cell; k^4 the normal one now continues simple to the antherid-zone, while k^5 forms by alternate tie-cells k^6 and k^9; k^7 and k^8 being a continuation of k^5.

The primary tie-cells are usually three for each cell of the generative filament, two lateral and one directly between the cell and the wall. According to the distance of the generative filaments from the wall, the tie-cells are long or short, clavate or pyriform.

After this study of the development of a primary mother-cell of the young sexual shoot into a sexually mature segment of the ripe sexual shoot, the appropriateness of the term segment, or sexual segment, becomes more apparent, since it is a structural and biological unit.

4. *Development of the Organs of Reproduction. Antheridia.* The antheridia arise from specialized cells which terminate the generative filaments, either normal or redundant. Fig. 12

shows the relation of the generative filaments to the antheridia in the subgenus *Sacheria*. Fig. 32 shows the same in the subgenus *Lemanea*. The terminal cells bear a resemblance in form to those of the medullary and intermediate layers; but they are richer in coloring matter and protoplasm. Fig. 35 represents a longitudinal section through an antherid-zone during the development of the specialized cells which bear antheridia; *b b'* are the last cells of the generative filament, which retain their form; *c c* are produced from *b b'*; *c c* in turn abjoint still smaller cells, which bear elongated columnar cells, *d d*. These last are the antheridiophores. Each one produces by growth at its outer extremity, usually one antheridium, sometimes two antheridia. It must be understood that in making the section other cells above and below were cut away, so that only a plane remains, while a cone-shaped group was developed from the ends of the cells next to the generative filaments. The columnar cells *d d*, the oval cells *c c*, and the smaller ones between, are very rich in coloring matter. At the time of anthesis, when the sexual shoot is translucent in other places, it is clouded in the antherid-zone, because of the presence of this rich coloring matter. Fig. 44 represents the clouded appearance of the cells which bear the antheridia. The antheridia are oblong, thin-walled sacs; each one contains an oblong, hyaline, non-motile spermatozoid, 8 μ–10 μ long, and about one third as wide.

The arrangement of the antheridia into variously shaped groups or patches bears a direct relation to the branching of the generative filaments. The affinities here show that the terminal branching of the generative filaments in the subgenus *Lemanea* is more profuse than in the subgenus *Sacheria*. Fig. 44, *Lemanea australis*, shows how all of the generative filaments meet, by their terminal branches, in a ring on the inner periphery of the wall, and there form a continuous antheridial ring, which is characteristic of the subgenus *Lemanea*. Where the ring is broken the branching is less profuse. Where the ring is irregular the terminations do not meet those of the adjacent segment evenly. In the subgenus

Sacheria the terminal branching not being so profuse, the antheridia are borne in patches upon the 'knots' or 'papillae.'

In some cases, by the examination of the external contour of a sexual shoot, antheridial patches can be found scattered irregularly over the surface of the procarp-zones. These arise from the terminations of redundant generative filaments, which are borne near the ray-cells and do not reach the antherid-zone. Fig. 44 *m* represents one of these. They are of frequent occurrence in the middle of well-developed portions of the sexual shoot of some species of the subgenus *Lemanea*, and of common occurrence in species of both subgenera near the distal extremity.

Development of the Procarp. The procarp arises as a special branch from the generative filament. It consists of several, three to ten or more, oval cells extending from the side of the generative filament between the cells of the wall; the terminal cell, carpogenic cell, is surmounted by the trichogyne, which penetrates through the intermediate layer and cortex to the outside of the sexual shoot. The trichogyne terminates as a simple short straight projection, or it is bent to one side, often slightly forked, and sometimes ending in several projections. See Figs. 13, 38, 39. The trichogyne is hyaline, the protoplasm very finely granular.

In the subgenus *Sacheria* the procarp consists of three or four cells. It is much shorter than in subgenus *Lemanea*, for the reason that in the latter subgenus the generative filaments are separate from the wall. Fig. 13 shows the three cells of a procarp in the subgenus *Sacheria* (*L. fucina*). The cells gradually become smaller from the generative filament to the trichogyne.

In the subgenus *Lemanea* the procarp is composed of four to ten or more cells. The individual cells are usually somewhat smaller than in the subgenus *Sacheria*, and are proportionately more nearly equal in size. The variations in the length of the procarp in the subgenus *Lemanea* depend principally upon the part of the generative filament from which it arises, since the filament is farther distant from the wall at the

origin from the ray-cell, and gradually approaches the wall toward the antherid-zone. Fig. 32 shows some of these variations. The development of the procarp proceeds with the branching which forms the layers of the wall, otherwise the trichogyne could not penetrate through the wall, which becomes quite compact by the pressure of the cells. It arises by the budding of a cell from the peripheral or radial face of the generative filament. This cell grows by elongation and transverse fission, forming a row of cells. Fig. 37 represents the procarp of six cells (subgenus *Lemanea*) just entering the space between two adjacent cells of the medullary layer, while the latter are producing by peripheral fission cells of the intermediate layer. One or more cells would now develop with the advancing development of the wall, and the trichogyne from the last one would pass out as the cortical cells are developed.

In the species of the subgenus *Lemanea* the origin of the procarp is chiefly in the middle region of the procarp-zone, near the ray-cells. In *Lemanea australis* a great majority are borne on the first and second cells of the generative filaments, while in *Lemanea annulata* they are distributed farther toward the antherid-zone, though never so close as in the subgenus *Sacheria*. In the latter subgenus they arise mainly in the two ends of the procarp-zone, reaching sometimes into the antherid-zone, or in some species, *Lemanea fluviatilis* for example, they also arise in the middle of the procarp-zone.

To correctly trace the origin of the procarp in the subgenus *Sacheria* a preparation should be made of a longitudinal half of a segment, so that the branching of the generative filaments can be seen. Fig. 11 represents such a preparation from *Lemanea fucina*. Nearly all of the procarps arise from the short branches of the generative filaments formed by the growth of a tie-cell into a short generative filament. Near the end of the generative filaments the cells become shorter and appear more like tie-cells in shape. A thin section by such a cell would make it appear that the procarp arose from a tie-cell. These redundant generative filaments may be so

short as to consist of only one cell beside the tie-cells which would unite them to the wall. In rare cases, should the procarp arise from a tie-cell, it (the tie-cell) should be considered the homologue of a redundant generative filament, as all tie-cells are.

Ketel[1] erred slightly in stating: 'Bei der Untergattung *Sacheria* (Fig. 22) entsprosst der Carpogonast, dessen Endzelle das "Carpogonium," die weibliche Sexualzelle, darstellt, gewöhnlich einer Verbindungszelle, selten einer Zelle einer wandständigen Zellreihe.'

Bornemann[2] erroneously states that all the procarps in both subgenera arise from the cells of the medullary layer, and devotes several pages to an attempt to refute Sirodot's[3] idea of the 'tubes latéraux.' There are also other evidences of careless observation by Bornemann. In Fig. 21. Taf. ii, he represents the spiral filaments around the central axis as arising from both the upper and lower face of the ray-cell, and as running up and down! He says[4], 'Die Anheftungszellen . . . aus ihnen entspringen dünne Zellfaden, welche nach oben und unten die axile Zellreihe spiralig umlaufen und mit ihr einen "axilen Strang" bilden.'

IV. Fertilization and Development of the Carpospores.

Fertilization. Fertilization takes place during contact of the spermatozoid with the point of the trichogyne. The secure passage of the non-motile spermatozoid to the trichogyne is provided for by the great numbers of spermatozoids, the tufts of sexual shoots in close contact, the action of the water providing movement of the individuals of a tuft, and the mucilaginous substance coating the sexual shoot. Probably contact is generally brought about by the antherid-zone of one individual resting against the procarp-zone of another.

[1] Anat. Untersuch. über *Lemanea*, p. 36, 1886.
[2] Beiträge zur Kenntniss der Lemaneaceen, pp. 26-32, 1887.
[3] Ann. d. Sci. Nat. Bot. 5th ser. xvi, 1872.
[4] Loc. cit. p. 10.

It is quite probable in many cases, especially in the subgenus *Sacheria*, where the antheridia and procarps are so near together, that the spermatozoid passes along in the mucilaginous coating to the trichogyne on the same individual.

In a number of sections of the sexual shoot, at the period of anthesis, I have been able to observe the spermatozoid in contact with the trichogyne during different stages of the process of fertilization: Fig. 13 represents the same in the subgenus *Sacheria* (*L. fucina*): Fig. 38 represents the same in the subgenus *Lemanea* (*L. australis*). In the latter, the end of the trichogyne is bifurcated and a spermatozoid is upon each process. Two, three, or several spermatozoids may be upon a single process of the trichogyne. The protoplasm of the spermatozoid is probably absorbed by the trichogyne and conveyed to the carpogenic cell, fertilizing it. The protoplasm of the spermatozoid is probably surrounded by a thin film, for in the progress of the absorption of its contents by the trichogyne it becomes shrivelled (Fig. 39). After fertilization the trichogyne also shrivels and finally disappears. Its granular contents first become yellowish, and the basal portion is separated from the slender portion, forming the carpogenic cell (Fig. 40). During the period of fertilization and the development of the carpospores, the entire apparatus of fructification is very rich in protoplasm, which indicates a high state of activity. It is richly colored with a yellowish, or yellowish-green, flocculent substance.

Development of the Carpospores. After fertilization, and the differentiation of the carpogenic cell at the base of the trichogyne, this cell develops, by budding, a whorl of cells, the ooblastema-filaments (Ooblastemfäden [1]), (not one ooblastema-filament as stated by Bennett and Murray [2]), which immediately, or after a few cells' growth, begin to branch and develop into a dense cluster of moniliform filaments, profusely branched, composed of short cells. The first cells, and sometimes the second and third, remain sterile and answer as

[1] Untersuch. über die Befrucht. d. Florideen, Fr. Schmitz.

[2] Cryptogamic Botany, 1889.

basidia. The remaining cells increase in diameter, become oblong, oval, or elliptical, and form moniliform chains of carpospores. Fig. 14 represents the slender articulated filaments developed from the whorl of cells: Fig. 16 shows them in a more advanced state of growth, the cells, a little distance from the carpogenic cell, becoming elliptical in outline, and the protoplasm more dense. The style of branching also can be seen; the branches first appear as minute buds from the side of the distal end of the young carpospore. Fig. 17 represents a farther development. The nucleus is here very distinct. Fig. 18 represents a portion of a cluster of fully developed carpospores. Figs. 14, 16, 17, 18, 58 and 60 are from the subgenus *Sacheria*.

In the subgenus *Lemanea* several or all of the cells of the procarp show a very profuse development of short-celled filaments. In many cases the entire procarp at the time of fertilization is literally covered with these outgrowths from the cells. By the time that the ooblastema-filaments are developed, the great mass of these vegetative buds, developed so close to the medullary layer, and partly within it, make it very difficult to ascertain whether more than one cell of the procarp functions as the carpogenic cell.

Sirodot[1] found difficulty here, and left it an unsettled question as to whether any of the cells, except the one at the base of the trichogyne, produced carpospores.

Ketel[2] found that only one cell produced carpospores; the vegetative buds from the other cells of procarp he regards as the homologue of the enveloping filaments in *Batrachospermum*.

My own researches corroborate Ketel's view. After making very thin sections, containing a procarp with young carpospores, the origin is still obscure, because the carpogenic cell is within the wall and because of the dense mass of vegetative buds from the procarp. By treatment of the preparation with chloral hydrate the young cell-walls are dissolved,

[1] Ann. d. Sci. Nat. 5th ser. Bot. xvi. p. 30, 1872.
[2] Anat. Untersuch. über *Lemanea*, 1886.

the protoplasm in all of the cells much contracted, the preparation cleared up, and the origin of the ooblastema-filaments can be distinctly traced to the cell differentiated at the base of the trichogyne. Fig. 15 is from *L.* (*Sacheria*) *fucina* Bory, and Fig. 41 is from *L. australis* Atk.

The moniliform series of spores are enveloped in a mucilaginous sheath till maturity, from which they escape during summer or autumn.

V. Branching of the Sexual Shoot.

Normal Branching. This takes place more frequently in the subgenus *Sacheria.* The branch arises from one of the young primary cells, the basal cell usually being one of the first cells, differentiated from the primary cell. In Fig. 9, *a* is the apical cell of the main sexual shoot, *b* is the apical cell of the branch. In such branching, where the branch arises from a primary cell of the main sexual shoot, the cavity of the branch communicates with that of the main one, and the branch has no pedicel. This seems to be the normal manner of branching. There are a number of exceptions showing different degrees of departure from it. The first step is where the generative filaments are already laid out, but in a rudimentary condition, and the peripheral development has reached only the tie-cells. A good example of this I found in *L.* (*Sacheria*) *fucina* Bory. At the point of origin of the branch a few of the tie-cells were undeveloped and the young branch of five primary cells was clearly seen to arise from the rudimentary generative filaments. In such a case the first cells of the branch would remain imperfectly developed, the branch would have a pedicel and its cavity would not communicate with that of the main sexual shoot. Other cases equal in degree to this departure are of quite frequent occurrence where the sexual shoot has been broken. Broken specimens develop abnormal branches, as well as the *Chantransia*-form, from the generative filaments, and a great many of the normal branches of this species (*L. fucina*) arise from

the zone where the procarps are developed, probably from a young procarp.

Apogamy and Apospory. A still farther departure from the normal manner of branching occurs frequently in *Lemanea annulata.* This I discovered while examining the external contour of the sexual shoots of some material from Santa Cruz, Cal. Very young sexual shoots were found growing from the surface of others which were in the period of anthesis. In the examination of several individuals I found that the young ones had their origin in a median zone of the procarp-zones. As this is the point where the greater number of procarps are produced, in the subgenus *Lemanea*, I at once inferred that the young sexual shoots had their origin from the procarp. Upon examination of several specimens carefully dissected I found my surmise to be correct. Fig. 45 represents one of the preparations. The young sexual shoot *b* consists of an apical cell and six primary cells; the two basal ones have begun to divide. The sexual shoot arises from the terminal cell of the procarp *g*, which is the fifth one of the procarp *a* from the generative filament *f*. In several cases I could clearly discern this in still younger sexual shoots. In other cases it appeared to arise from the cells which bud off from the other cells of the procarp, in this subgenus. This view would also seem to be justified from some specimens which presented a crowded cluster of young sexual shoots arising directly out of the wall at a procarp, but all such cases which I examined were in a too advanced condition of development to determine accurately.

In material of the subgenus *Sacheria* (*L. fucina*) collected in Island Brook, Bridgeport, Conn., I have observed elements of the *Chantransia*-form growing from the cells of a procarp, probably, which at the same time developed a branch of the main sexual shoot. In specimens of *S. fucina* from Ithaca, N. Y. branches of the sexual shoot have been found to arise where the main sexual shoot is broken. In a number of such I have demonstrated that the branch arose from the generative filament, and its basal cells developed the *Chantransia*-form.

I have a microscopic mount of such a preparation in my possession.

In the cases where the terminal cell of the procarp produces a sexual shoot it is impossible to tell whether it is before or after fertilization. If after fertilization it would be a case of apospory; if before fertilization it would be a case of apogamy[1]. By far the greater number of cases of abnormal branching come under the head of apogamy, where the procarp, or generative filament, produces either one of the three forms of the oophyte. In this connection it seems interesting as indicating that the procarp of the Lemaneaceae is a modified main branch of the sexual shoot.

In view of these facts I am led to believe that Bornemann[2] mistook similar cases for what he thought was the development of the *Chantransia*-form and young sexual shoots from the cortex of the main sexual shoot.

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VI. Systematic Part.

Family LEMANEACEAE.

Sexual shoots cartilaginous, simple or branched, elongate, cylindrical, tubular, torulose with the regularly recurring enlargements well marked or barely perceptible; central axis naked or covered by slender filaments; ray-cells in whorls of four in the middle of each procarp-zone; generative filaments lying longitudinally along the interior face of the wall, producing laterally the procarps, terminally the antheridia. Antherid-zones smooth, angular, or knotty: antheridia numerous, produced in well-defined patches or bands on the external face of the antherid-zone. Procarps of three to several oval cells, the terminal one, carpogenic cell, within the tissue of the wall, the trichogyne penetrating to the exterior. Carpospores oval, oblong, or spherical, produced in dense clusters of radiating,

branched, moniliform chains on the interior of the sexual shoot. Developed as lateral shoots from the *Chantransia*-form, of a greenish, yellowish-olive, violet or purple color, sometimes changing color in drying. Annual.

Protonema. Chantransia-form of erect, branched, confervoid filaments of limited apical growth, not producing gonidia, greenish or violet, developed as lateral shoots from the prostrate form, rarely from the spores. Autumnal, fugacious. Prostrate form, cellular, or with matted creeping confervoid filaments, of unlimited apical growth, fixed to the substratum, produced from the spores and by growth from the basal cells of the *Chantransia*-form. Perennial.

Habitat, on rocks or wood-work, etc. in fresh-water streams at rapids, falls, etc., in turbulent or swift waters. Period of development, October to June.

Genus LEMANEA[1] Bory, Emend. C. A. Ag.

Apona Adans., Fam. d. Plantes, ii. 1763.

Polysperma Vauch., Hist. d. Conferves, 1803.

Chantransia D. C., Flore Française, vi. 1805.

Lemanea Bory, Ann. d. Mus. Hist. Nat. 1808; C. A. Ag. Species Alg. pp. 1–8, 1824–28; Kütz., Species Alg. et Tab. phyc. 1849; Rabh., Flora Europ. etc. iii. 1864–68;

[1] The genus *Lemanea* as established by Bory (in honor of M. Leman, a French naturalist) included several species of plants now known under the genus *Batrachospermum*, loc. cit. He might well have emended *Polysperma* of Vaucher, since the *Conferva fluviatilis* of Linn. was made by Vaucher the type of his genus (see note below); or, even better, have adopted the *Apona* of Adanson which Desveaux (loc. cit.) regretted he did not do. Bory gives no reason for rejecting *Apona* Adans., but his reason for not adopting *Polysperma* (loc. cit. p. 178) was that Vaucher included in the genus a widely different plant, *Conferva glomerata* Dill. C. A. Agardh (loc. cit.) emended the *Lemanea* of Bory so as to include those forms now regarded as constituting this genus. However great the claims of justice may seem to be for *Polysperma* or *Apona*, it seems wiser to prevent needless confusion by retaining a name which for three-quarters of a century has met with universal acceptance, and though in itself inexpressive of any character, yet conveys to the minds of botanists the familiar habit of these plants.

Note.—Bory, as well as some later writers, did Vaucher injustice in thinking he had not observed the spores and their germination in *Polysperma fluviatilis*. On the other hand, Bory could find no spores, and erred in thinking the plants reproduced by the separation and growth of the papillae!

Sird't., Ann. d. Sci. Nat. 5th Ser. Bot. 1872; Wolle, Fresh Wat. Alg. U. S. 1887; Born'm., Beit. z. Kennt. d. Leman. 1887.

Trichogonus Palisot; see Desveaux, Jour. Bot. p. 124, 1808.

Vertebraria Rouss.; see Desv., Jour. Bot. i. p. 143, 1808.

Nodularia Link, Neues Jour. Bot. p. 9, 1809; Lyngb., Tent. Hydrophyt. dan. p. 99, 1819.

Gongycladon Link; see Jahresb. ü. d. Arb. f. Phys. Bot. vi.

Sacheria Sird't., Ann. d. Sci. Nat. 5th Ser. Bot. 1872; Born'm., Beit. z. Kennt. d. Leman. 1887.

Entothrix Wolle, Bull. Torr. Bot. Club, p. 183, 1877.

Tuomeya Wolle, Fresh Wat. Alg. U. S. ex parte, 1887.

Characters those of the family.

Subgenus LEMANEA.

Antheridia in bands, regular or interrupted, around the antherid-zone. Procarps of five to ten cells, always developed in the middle of the procarp-zone, never so near the antherid-zone as in the subgenus *Sacheria*; ray-cells simple, not reaching the wall; central axis soon surrounded with slender filaments developed from the lower face of the ray-cells; generative filaments far separated from the wall except in the antherid-zone, normal number at first six above and eight below the ray-cells, soon becoming eight above by the branching of two opposite first cells: cortex sometimes in two to three layers of cells developed serially; basidia (first cells of ooblastema-filaments) short, oval; hypogynous cells of the procarp producing short-celled filaments (paraphyses?) at time of fertilization; prostrate form of the protonema mainly confervoid. In turbulent water, or rather slow running water of strong streams.

1. **Lemanea annulata** Kütz.

Lemanea annulata, Kütz., Species Alg. et Tab. phyc.

1849; Rabh., Flor. Europ., etc. iii. 1864–68; Sird't., Ann. d. Sci. Nat. 1872.

Lemanea catenata Wood, Fresh Wat. Alg. U. S. 1872; Wolle, Fresh Wat. Alg. U. S. 1887.

Lemanea fluviatilis Wolle, Fresh Wat. Alg. U. S. ex parte, 1887.

Chantransia-form 2 mm. to 3 mm. long, of a dark violet color unless faded with age; cells 30 μ. to 40 μ. in diameter, filaments of nearly the same diameter throughout; branching below alternate, then unilateral, alternate or rarely opposite.

Sexual shoot arising at the ends of a principal axis of the *Chantransia*-form, or on a short branch, confined near the base, of a violet color when young, sometimes fading out in age, young ones blacking when dry; usually simple, sometimes branched, the branches fasciculate, developing from procarps in the middle of the procarp-zone. Sexual segments regularly constricted; antherid-band at the time of fertilization broad, usually regular, sometimes interrupted near the base; at the time of fertilization antherid-band of a lighter color than the adjacent parts when in water. Antherid-zone sometimes increasing after fertilization by hypertrophy of the tissue at the base of the antheridia. Procarps developed in the middle of the procarp-zone.

Habitat. Santa Cruz, Cal., Dr. C. L. Anderson; Oakland, Cal.; Eastern Oregon, W. C. Cusick, No. 1353; Diamond Mts. Nevada, Sereno Watson, U. S. Geol. Expd., 4cth Parallel, No. 1546; California (Herb. Wolle, *L. fluviatilis*).

Note. At the time of fertilization this species is readily determined by the strong contrast, when in water, in color of the antherid-band with the procarp-zone. After fertilization this is not so distinct, but the tissue beneath the antheridia in the band can easily be seen under the microscope. Specimens dried when nearly or quite mature often lose nearly all or all of the violet color; but as they mature there appears a dark region in the middle of the procarp-zone which has the appearance of a dark band, narrow when the spores are quite young, but broader when they are mature,

sometimes the ends of the moniliform chains of spores reaching nearly to the antherid-band, so that the entire procarp-zone is crowded with and darkened by the mass of spores. When dry and mature, or nearly so, the antherid-band is often constricted because of the presence of spores in the procarp-zone. By moistening the sexual shoots in water, unless too old, the enlargements (antherid-zone and neighboring parts) are regularly fusiform. This readily distinguishes *L. annulata* Kütz. from *L. catenata* Kütz.: in *catenata* the segments are dumb-bell shaped, while in *annulata* they are hour-glass shaped; *catenata* is darker in color in age than *annulata*, usually, and more rigid, agreeing in this respect more with *L. nodosa* Kütz. which Rabenhorst (loc. cit.) makes a synonym of *catenata*; the walls of *annulata* are thinner and more delicate.

After comparing the specimens collected by Sereno Watson, which Wood (loc. cit.) determined as *L. catenata* Kütz., with a series of specimens of *L. annulata* from California and Oregon in different stages of development, and with *L. catenata* from Herb. Crypt. Belg. 696; Rabh. Alg. Europ. 1379; and Alg. de la France 288, I am convinced that this *L. catenata* of Wood, which Prof. D. C. Eaton of Yale University kindly loaned me, is *L. annulata* Kütz. The 'dark bands' which Wood (loc. cit.) speaks of are caused by the young spores.

2. **Lemanea torulosa** Sird't.

Lemanea incurvata Bory, Ann. d. Mus. ex parte, 1808.

Lemanea torulosa Kütz., Tab. Phyc. vol. vii. pl. 84, Fig. 2 exclud.; Wolle, Fresh Wat. Alg. U. S. ex parte, 1887.

Chantransia-form in tufts, branches pencilled, appressed, alternate, primary ones sometimes opposite, about 3 mm.

Sexual shoots of an olive or olive-green color, darker when dry, arising from the basal cells of the *Chantransia*-form, somewhat arcuate, slightly undulate. Procarp-zone only slightly sloping from the antherid-zone to the middle, where

it is narrowly constricted, especially at maturity. Antherid-band narrow, irregular, often interrupted.

The only specimens of this species I have seen from the United States were from Herb. Wolle, marked 'On stones Mt. rivulet, July 1, 1874, Narrows.'

3. **Lemanea nodosa** (?) Kütz.

Some small specimens of a mature *Lemanea* were collected by me in the James river, Richmond, Va., and Rappahannock river, Frederickburg, Va., which seem to agree most nearly with small forms of *Lemanea nodosa* Kütz. Pending a complete study of the different stages I refer the specimens provisionally to this species. The following characters can be given.

Chantransia-form in tufts, branches attenuated at base, alternate, sometimes unilateral above, pencilled.

Sexual shoots of a violet color, blacking when dry. Antherid-zones of fertile portions prominent, procarp-zones nearly cylindrical; antherid-band broad, irregular, sometimes interrupted near base. Procarps in middle of procarp-zone. Sexual shoots straight or slightly arcuate.

4. **Lemanea australis** Atk.

Chantransia-form in dense tufts or in unbroken patches, yellowish or bluish-green, of two forms, sterile form 4 mm.–5 mm., fertile 2 mm.–3 mm. Branching alternate, or rarely unilateral, or opposite at base, pencilled when crowded, corymbiform when quite free, slender at base, gradually increasing in size to middle region, where the cells are very large, sometimes nearly spherical.

Sexual shoots green, when young not blacking by drying, in age blacking or darkening when dry, confined to the base of the *Chantransia*-form, either from a short principal axis, or a short branch; stout; sterile base gradually enlarging to fertile portion. Fertile segment nearly plane at base, strongly constricted at time of fertilization in the middle region and nearly plane at the distal end; cortex of mature specimens in two layers of cells; antherid-band narrow and interrupted

near the base, perfect and irregular in middle region, and broad and regular at the distal end. At maturity antherid-band sometimes constricted because the tissue here ceases to grow, sometimes prominent by hypertrophy, when a prominent ring is formed. Procarps in the middle of the procarp-zone. Spores 35 μ–45 μ.

Note. This species is subject to great variations dependent upon the nature of the stream. Where the water is shallow and not very swift, the sexual shoots are strongly arcuate, short, and very stout. In deep water with a strong current they are nearly straight, and stout. In deep water where the current eddies below rocks, or is slow, they are stout at base, and the remainder capillary during the period of fertilization; but if they mature before the capillary portions are broken away, they are generally stout throughout. Some of the largest specimens of this species I collected in the Broad river at Columbia, S. C. In Morgan's Creek, Chapel Hill, N. C., specimens of the arcuate form were found on a level rock at the head of the upper rapids, Otey's retreat. At lower rapids there is a place where the water is never lower than 25 cm.–40 cm. and is always comparatively slow. Here grow specimens of the sterile *Chantransia*-form, which develop from year to year without producing sexual shoots. Near this, in the turbulent water, the *Chantransia*-form is fertile. At Columbia, S. C., the fertile *Chantransia*-form is somewhat smaller.

5. **Lemanea grandis** Atk.

Entothrix grande Wolle, Bull. Torr. Bot. Club, 1887; Wolle, Rab. Alg. Europ. 2538.

Tuomeya grande Wolle, Fresh Wat. Alg. U. S., pl. 66, Figs. 2–8, 1887.

Chantransia-form unknown, as the material was collected in midsummer. Sexual shoots olive-brown or blackish, rather slender, arcuate, very slightly undulate in the more fully developed specimens; cortex of two to three layers of cells at maturity; central axis with surrounding filaments very compact and tough; walls of the sexual shoot very rigid at

maturity and brittle when dry. Antherid-zone not prominent; antherid-band broad as shown by the marks of the basal tissue remaining after fertilization; procarps in the middle of the procarp-zone; spores often aborted and undeveloped: mature ones large, ovoid or spherical; 31 μ–45 μ.

Note. I have carefully examined specimens of this species from Wolle's herbarium [1], and from Rabenhorst's Alg. Europ. No. 2538, and find it to be a *Lemanea*. Through the kindness of Dr. W. G. Farlow I have had the opportunity of examining specimens of *Tuomeya fluviatilis* Harv. from Harvey's herbarium. It is very different from Wolle's *Tuomeya grande* (*Entothrix grande* Wolle). I have made careful dissections and find Wolle's *Entothrix* is identical with the characters of the subgenus *Lemanea*. Fig. 46 represents a section showing the enveloping filaments dissected away from the central axis at the point where the cruciate branching of the ray-cells occurs. The dissection was also made to show the origin of the spores: *a* represents the procarp, the chains of spores radiate from the region of the carpogenic cell. It is so firm at maturity that it is necessary to use patience and care in removing the filaments which surround the central axis. With little difficulty however the procarps are found. The interlacing of filaments on the interior of the tube is common in some other species of *Lemanea*. The cortex develops two to three cell-layers, as in *L. nodosa* Kütz. and *L. australis* Atk. Sometimes by hypertrophy of the tissues of the antherid-zone several more layers are developed.

Habitat. 'In shallow, sluggish river water,' Bethlehem, Pa. Some younger specimens of a *Lemanea* collected at Falkland, Del., by Mr. Commons (Herb. W. G. Farlow), I have referred to this species. Mr. C. H. Green, Chester, S. C., collected specimens of a *Lemanea* in the Catawba river, which

[1] During the winter of 1887–88 the author received specimens of this species from the herbarium of Rev. Francis Wolle, and discovered it to be a *Lemanea*, but did not publish it at the time as it was considered to be more valuable to hold it until the completion of the present Monograph.

were determined by Wolle as *Tuomeya grande.* Mr. Green kindly sent me some specimens. They probably belong to *L. australis* Atk.

Subgenus SACHERIA.

Antheridia in well-defined patches, rarely confluent, antherid-zone plane or papillate; procarps of 3–4 cells, always developed in and near the antherid-zone, in some species also borne in the middle of the procarp-zone; ray-cells T- or L-shaped, the arms closely applied to the wall; generative filaments closely applied to the wall throughout their entire length, normal ones at first four above and four below the ray-cells, becoming six above by branching of the first cell of two opposite filaments; basidia (first cells of ooblastema-filaments) elongate, cylindrical; hypogynous cells of the procarp naked; prostrate form of protonema mainly cellular. In very turbulent water.

6. **Lemanea (Sacheria) fluviatilis** Ag.

Conferva fluviatilis Linn.

Polysperma fluviatilis Vauch., Hist. d. Conferv. 1803.

Chantransia fluviatilis D. C., Flore Française, vi. 1805.

Lemanea corrallina Bory, Ann. d. Mus. 1808.

Lemanea fluviatilis Ag., Spec. Alg. 1824–28; Kütz., Spec. Alg. et Tab. Phyc. 1849; Rabh., Flora Europ. iii. 1864–68.

Sacheria fluviatilis Sird't., Ann. d. Sci. Nat. 1872.

Chantransia-form in dense tufts, branches alternate, final branching sometimes opposite or fasciculate, pilose.

Sexual shoot confined to the lower cells of the *Chantransia*-form, or in the middle branching, of a dark violet color, generally blacking when dry, usually reddening the water in which they stand, long, slender pedicelled, often simple, frequently branched, branches often fasciculate. Procarp-zone cylindrical. Antherid-papillae in verticils of 3–4, little prominent, rather distant and regular but nearer towards the distal end. Procarps developed all along the generative filaments from the first cell as well as from the cells in the antherid-zone.

Note. By noting the origin of the procarps it is quite easy to separate *fluviatilis* from some forms of *fucina* which have been confounded with it.

Habitat. Fragments of specimens from Oregon, in Herb. W. G. Farlow. I have had the opportunity of examining *L. corrallina* Bory, Libert. Plant. Crypt. Ard. 100, and *L. fluviatilis* Ag. Rabh. Alg. Sachs. 299.

7. **Lemanea (Sacheria) fucina** Bory.

Chantransia dichotoma D. C., Flore Française, vi. 1808.

Lemanea fucina Bory, Ann. d. Mus. 1808.

Lemanea subtilis Ag., Spec. Alg. 1824–28.

Lemanea torulosa Kütz., Spec. Alg. et Tab. Phyc. vol. vii. pl. 84, Fig. 2; Wolle, Fresh Wat. Alg. 1887, ex parte.

Lemanea mamillosa Kütz., Spec. Alg. et Tab. Phyc. 1849.

Lemanea fucina Rabh., Flora Europ. etc. iii. 1884–68.

Lemanea fluviatilis Wolle, Fresh Wat. Alg. U. S. ex parte, 1872; Wolle, Fresh Wat. Alg. 1887, ex parte.

Sacheria fucina Sird't., Ann. d. Sci. Nat. 1872.

Sacheria mamillosa Sird't., Ann. d. Sci. Nat. 1872.

Sacheria rigida Sird't., Ann. d. Sci. Nat. 1872? (Middlesex Flora, 1888, p. 153, Dame and Collins).

Chantransia violacea[1], var. *Beardslei*, Wolle, Bull. Torr. Bot. Club, 1879; Fresh Wat. Alg. U. S. 1887, p. 60, Fig 14, pl. 68.

Chantransia-form producing extensive mats or circumscribed tufts, greenish or bluish-green, 1 mm.–2 mm. long, primary branches usually alternate, final branching unilateral, alternate, or sometimes opposite or slightly fasciculate, sometimes pilose, filaments not much attenuated at base, 15 μ–35 μ in diameter.

Sexual shoots before maturity olivaceous, or yellowish-

[1] This is the *Chantransia*-form of *Lemanea* (*Sacheria*) *fucina* Bory var. *rigida*, which Wolle found 'as an undergrowth, intermingled with *Lemanea*, which was fringed with the parasitic *C. violacea*,' from Painesville, Ohio.

green, sometimes of an obscure tint of violet, sometimes reddening the water in which they stand, confined to the basal cells of the *Chantransia*-form or arising in the middle branching. When young usually preserving color in drying. In age drying yellowish, greenish, or blackish; from 2 cm.–40 cm. long, very delicate or stout, usually pedicelled by an abrupt contraction at the beginning of the fertile portion, strongly so in stout specimens; simple or very much branched; branches distributed all along the main axis of the sexual shoot; main axis reaching beyond the branches and easily traced, or indistinguishable from them; branches unilateral, or fasciculate or both; when profusely branched the final branches slender, often capillary, stouter in age by the breaking away of the capillary summits. Procarp-zone nearly cylindrical, or constricted in the middle; antherid-papillae plane or prominent, so that the sexual shoot varies from cylindrical to torulose, or with regularly recurring whorls of prominent papillae. Papillae in verticils of two to seven, sometimes irregular, often confluent, sometimes increasing after fertilization by hypertrophy of the tissue beneath the antheridia, so that they are very prominent in age, sometimes less prominent after fertilization; procarp-zones in some specimens strongly constricted just above the antherid-zone, so that with the next antherid-zone it appears nearly clavate, more strongly so in age and toward the distal end of the sexual shoot. Antherid-zones sometimes distant, sometimes rather near each other. Procarps developed in and near the antherid-zone, never in the middle of the procarp-zone, so that at maturity the clusters of spores alternate with the sterile middle portions of the procarp-zone; spores when mature giving a darker color to the sexual shoots.

This species, as limited here, is very widely distributed and subject to great variations. Beside the *fucina* of Bory, I have included in it the *rigida* and *mamillosa* of Sirodot (*Sacheria rigida* et *S. mamillosa*). Sirodot's characterization of the *Chantransia*-form of *rigida* and *fucina* differs only in that the sexual shoots arise from the basal cells in *rigida*, while in

fucina they arise also in the middle branching, and the ends are pilose. I have studied good specimens of *rigida* from Ithaca, N. Y., in all stages of development. In these the sexual shoots arise also in the middle branching, and the ends of the branches are sometimes pilose. The other differentiating characters given are that *rigida* is stouter (though Sirodot admits some slender forms), and the papillae are sometimes more numerous and often confluent. Kützing[1] made *fucina* Bory, and *subtilis* Ag., each varieties of his *mamillosa*, and *dichotoma* D. C. a synonym. Rabenhorst[2], giving priority to Bory's species, made *subtilis* a variety of *fucina* Bory, and reduced both *mamillosa* Kütz. and *dichotoma* D. C. to synonyms. Sirodot[3], instead of uniting them all under one variable species, as he should have done, followed Bory in upholding the specific identity of *fucina* and *dichotoma*, rejecting the name *dichotoma*, for which he used *rigida*. He then made *mamillosa* a species, although he had no specimens of the *Chantransia*-form of this variety, and his specimens of the variety *subtilis* indicated the transition of *mamillosa* to *fucina*; but he refrained from uniting them until the *Chantransia*-form of *mamillosa* and var. *subtilis* should be compared with that of *fucina*. I have had some very fine specimens of *subtilis* from the 'Cascades,' Melrose, Mass., and the *Chantransia*-form is identical with that of *fucina* as characterized by Sirodot.

I have specimens from Bolan's Creek, Chapel Hill, N. C., which I at first referred to *mamillosa* Sird't., so regularly did the papillae and color of the young sexual shoots agree with that form, though the branching was not quite so profuse. But variations in some of the material appeared, and specimens of the same species from Morgan's Creek, Chapel Hill, N. C., showed a farther departure, and agreed in the *Chantransia*-form and papillae (3–7 often confluent) with *rigida* Sird't., and many specimens varying to *mamillosa* Sird't. Sirodot recognized great variations in size and branching in his *rigida*.

[1] Loc. cit. [2] Loc. cit. [3] Loc. cit.

With the large series of forms before me it is impossible to select any important stable character which will differentiate them into good species, otherwise one could make a species for specimens from nearly each different locality. The variations of the antherid-zone and papillae are explained by the variations of the branching of the ends of the generative filaments, which we find varies in the same specimen. I am led then only to enlarge the specific characters of the *Chantransia*-form of *rigida* Sird't., and in view of the unity of essential characters in the large series of forms, to follow Kützing and Rabenhorst in uniting them into one variable species, and to give priority to Bory's name.

Among all these variations there are some forms about which many may be more or less definitely grouped:—

Var. α, **mamillosa**, stout, procarp-zones cylindrical or nearly so, papillae very prominent at time of fertilization, sometimes more so in age by hypertrophy of the tissue at base of antheridia, sometimes confluent; young sexual shoots of an obscure violet colour, reddening the water in which they stand. for several days, confined to the basal-cells of the *Chantransia*-form. In age drying yellowish.

Habitat. Morgan's and Bolan's Creek, Chapel Hill, N. C., collected by the author. Alabama, T. M. Peters, Coll. (Herb. Boston Soc. of Nat. Hist.).

Var. β, **subtilis**, very capillary, profusely branched, papillae 3–5, rarely confluent, procarp-zones cylindrical, or sloping from the antherid-zone; sexual shoots at various heights in the *Chantransia*-form. In age drying yellowish.

Habitat. 'Cascades,' Melrose, Mass., F. S. Collins and W. A. Setchell.

Var. γ, **rigida**, simple or branched at various lengths in the *Chantransia*-form; procarp-zones nearly cylindrical or strongly constricted; papillae nearly or quite plain, 3–7, often confluent. In age usually drying yellowish, sometimes obscured by the greenish or dark color of the

spores clustered in the antherid-zones, rarely fading so as to be nearly colorless.

Habitat. Mill Brook, Shelbourne, N. H., Dr. W. G. Farlow; Bussey Brook, Jamaica Plains, Mass., Miss Clark, and Mr. Faxon (ex parte); Belleville, Ont., J. Macoun; Painsville, Ohio, streams of Pa. and some other places, not noted on specimens from Herb. Rev. Francis Wolle; Island Brook, Bridgeport, Conn., specimens little branched, Isaac Holden; specimens simple, and appearing to vary in form of antherid-zone to the next variety, Isaac Holden and W. A. Setchell; Franklin, Conn., W. A. Setchell; Westrock Cascade, New Haven, Conn., D. C. Eaton; Sargent's River, Woodbridge, Conn., O. D. Allen; Little Otter Creek, Ferrisburg, Vt., Mr. Faxon; Ithaca, N. Y., Prof. W. R. Dudley and J. M. Stedman; Oregon, Elihu Hall; small specimens from San Bernardino, Cal., S. B. Parish; Ellenville, N. Y., Mrs. Britton; Nepsiquit river, N. B., J. Fowler; Pirates' Cove, Nova Scotia, J. Macoun.

Var.[1] δ, **viviana**, stout, profusely branched, procarp-zone with antherid-zone next above somewhat clavate, especially at maturity and near the distal end; papillae 3–7, often confluent, prominent in age; tending to blacken by drying when mature.

Habitat. Island Brook, Stillman's Brook, Conn., Isaac Holden; Bussey's Brook, Jamaica Plains, Mass., Mr. Faxon (branched forms).

Specimens too young for characterization, but probably belonging to this species, were sent me by Prof. Edward Burgess, collected at Harper's Ferry.

[1] I have used the name which Sirodot gave to a variety of his *rigida*, with which these specimens agree.

EXPLANATION OF FIGURES IN PLATES VII, VIII, and IX.

Illustrating Mr. Atkinson's Monograph of the Lemaneaceae of the United States.

PLATE VII.

Lemanea (*Sacheria*) *fucina* Bory var. *α*, *mamillosa*.

Fig. 1. Spore germinating and producing confervoid elements of prostrate form of the protonema.

Figs. 2, 3, and 4. Same producing cellular prostrate form.

Fig. 5. *a*, Cellular prostrate form; producing *Chantransia*-form, *b*.

Lemanea (*Sacheria*) *fucina* Bory var. *γ*, *rigida*.

Fig. 6. *Chantransia*-form producing sexual shoot in middle branching; *c*, sexual shoot; *b*, rhizoid; *d*, cellular prostrate form produced by rhizoid.

Fig. 7. End of developing sexual shoot showing manner of fission of the primary cells.

Fig. 10. *Chantransia*-form producing young sexual shoots *cc* on branches.

Lemanea (*Sacheria*) *fucina* Bory var. *α*, *mamillosa*.

Fig. 8. *Chantransia*-form with base of young sexual shoot *c*, and rhizoids producing cellular prostrate form *a* and *a'*. *Chantransia*-form is old, and main filaments broken away, so that they appear shorter than when in good condition of development; shows arrangement of endochrome.

Fig. 9. End of young sexual shoot showing origin of normal branch *b*.

Fig. 11. Longitudinal section of part of sexual segment at time of fertilization, showing branching of generative filaments and origin of procarps. *a*, central axis; *b*, ray-cell; *c*, descending generative filament; *d*, tie-cell; *x*, ascending generative filaments, two arising from end of arm of ray-cell (T-cell); *e*, procarps; *f*, antherid-papilla.

Fig. 12. Section of antherid-papilla at time of anthesis; *a*, generative filament; *b*, procarp; *c*, antheridium; *d*, spermatozoid.

Fig. 13. Section of procarp-zone showing part of wall and procarp at time of fertilization. *a*, procarp; *b*, trichogyne; *c*, spermatozoid.

Fig. 14. Same after fertilization. *a*, procarp; *b*, generative filament; *c*, place where trichogyne atrophied; *d*, cortex; *e*, cells of intermediate layer; *f*, of medullary layer; *g*, ooblastema-filaments.

Fig. 15. Same a little farther developed treated with chloral hydrate to show origin of ooblastema-filaments from carpogenic cell. *a*, carpogenic cell; *b*, cells of the ooblastema-filaments which become the basidia; *c*, cells which develop into carpospores.

Figs. 16 and 17. Same farther developed.

Fig. 18. Part of fully-developed cluster of carpospores.

Lemanea australis Atk.

Fig. 19. Spore germinating and producing an element of the confervoid prostrate form.

Fig. 20. Same producing *b* element of confervoid prostrate form and a young axis of *Chantransia*-form.

Fig. 21. Farther advanced condition of development of the two forms of protonema from a spore.

Fig. 22. Spore producing *bb* two axes of prostrate form, and *d* one axis of *Chantransia*-form; *cc*, other axes of *Chantransia*-form developed, the main axis of which is producing a young sexual shoot of two cells growth at time of making the drawing. *a*, elements of the confervoid prostrate form developed both from the spore and from the basal cells of the *Chantransia*-form.

PLATE VIII.

Lemanea australis Atk.

Fig. 23. Mode of branching of main axis of *Chantransia-form*; *a*, rhizoid.

Fig. 24. Well-developed fertile *Chantransia*-form where the tuft was not crowded.

Fig. 25. Branch of same farther developed.

Fig. 26. Sterile *Chantransia*-form.

Fig. 27. Portion of *Chantransia*-form showing arrangement of endochrome in mature and young cells.

Fig. 28. *Chantransia*-form producing a rhizoid *a*, from which is developed a fertile axis of *Chantransia*-form *b*, bearing a young sexual shoot, *c*.

Fig. 29. Portion of young sexual shoot showing fission of primary cells.

Fig. 30. Cross section showing the first whorl of four cells differentiated from the central axis.

Fig. 31. Longitudinal section of one half of young segment showing centrifugal development. *a*, central axis; *b*, ray-cell; *c*, generative filament.

Fig. 32. Section of procarp-zone at time of anthesis showing ray-cells, *b'' b'''*; central axis, *a*; enveloping filaments, *c*; generative filaments, *dd''*; procarp, *e*; antheridia, *g*.

Fig. 33. Section through young antherid-zone.

Fig. 34. Farther development.

Fig. 35. Section showing relation of generative filament to antheridiophores (the cylindrical cells which bear antheridia).

Fig. 36. Section of antherid-zone at time of anthesis; *c*, antheridiophores; *d*, antheridia; *e*, spermatozoid.

Fig. 37. Section of procarp-zone. *a*, generative filament; *b*, young procarp.

Fig. 38. Same at time of fertilization. *c*, sterile filaments (paraphyses?) produced from the hypogynous-cells of the procarp; *d*, trichogyne; *e*, spermatozoids.

Fig. 39. Same at time of differentiation of carpogenic cell at base of trichogyne.

Fig. 40. Same in a later stage before the beginning of growth of the ooblastema-filaments.

Fig. 41. Same later, showing development of spores from the ooblastema-

filaments: treated with chloral hydrate to show origin of ooblastema-filaments from carpogenic cell.

Fig. 42. Farther development of spores.

PLATE IX.

Lemanea australis Atk.

Fig. 43. Few fully developed spores with a double gelatinous sheath.

Fig. 44. Arrangement and branching of generative filaments in one half of segment, showing also position of procarps (longitudinal section).

Lemanea annulata Kütz.

Fig. 45. Section of procarp-zone showing development of procarp into a young sexual shoot; *f*, generative filament; *a*, procarp; *g*, terminal cell of procarp; *b*, young sexual shoot; *d*, cells of intermediate layer beginning to produce cortex.

Lemanea grandis Atk. (Syn. *Tuomeya* (*Entothrix*) *grande* Wolle).

Fig. 46. Section showing *Lemanea*-structure, enveloping filaments dissected away to show cruciate branching of rays from central axis. *a*, procarp reaching from generative filament into tissue of wall, from which point the basidia (bases of ooblastema-filaments) radiate and bear the spores.

Fig. 47. *Lemanea australis* Atk.

Fig. 48. *Lemanea nodosa* (?) Kütz.

Fig. 49. *Lemanea annulata* Kütz.

Fig. 50. *Lemanea grandis* Atk.

Fig. 51. *Lemanea torulosa* Sird't.

Fig. 52. *Lemanea* (*Sacheria*) *fluviatilis* Ag.

Fig. 53. *Lemanea* (*Sacheria*) *fucina* Bory var. δ, *viviana*.

Fig. 54. *Lemanea* (*Sacheria*) *fucina* Bory var. β, *subtilis*.

Fig. 55. *Lemanea* (*Sacheria*) *fucina* Bory var. α, *mamillosa*.

Fig. 56. *Lemanea* (*Sacheria*) *fucina* Bory var. α, *mamillosa*, natural size of large specimen.

Fig. 57. *Lemanea australis* Atk., natural size of large specimen.

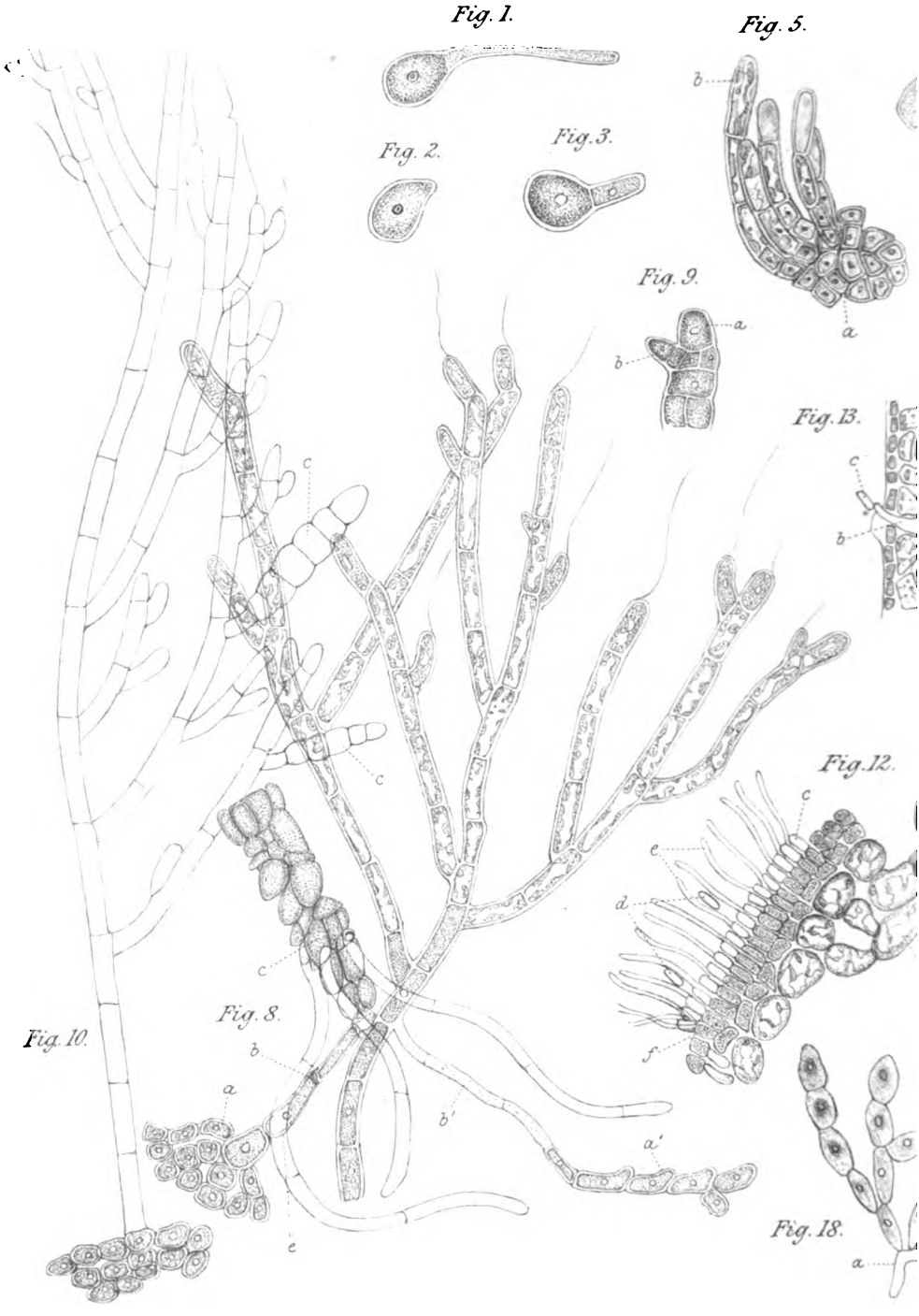
Fig. 58. *Lemanea* (*Sacheria*) *fluviatilis* Ag., section of sexual segment showing position and arrangement of spores.

Fig. 59. *Lemanea australis* Atk., same as last.

Fig. 60. *Lemanea* (*Sacheria*) *fucina* Bory var. α, *mamillosa*, same.

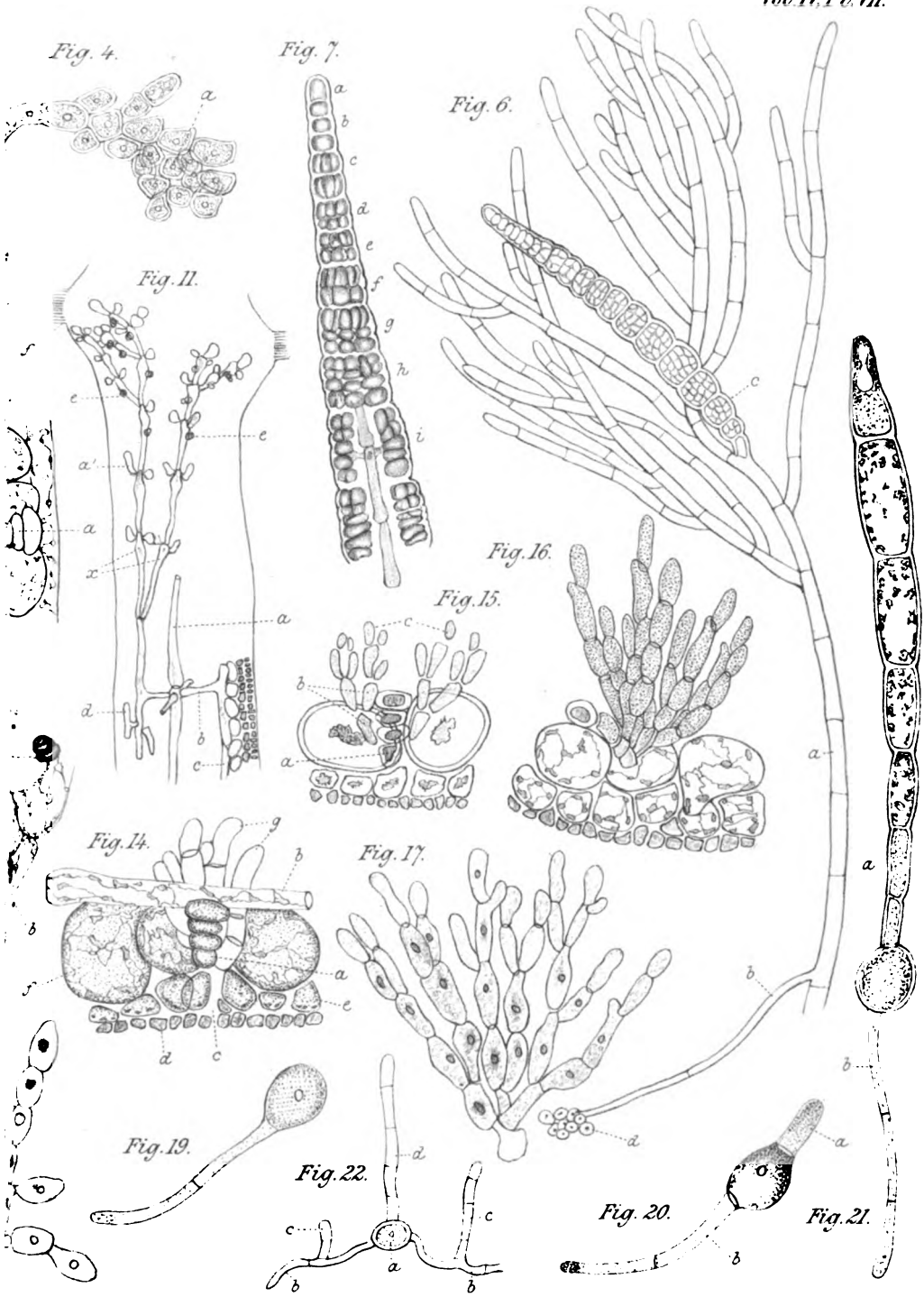
MAGNIFICATION OF FIGURES.

Figs. 1, 2, 3, 4, 5, 7, 8, 9, and 10 about 250; Fig. 6 about 150; Figs. 12-21 about 200; Figs. 22-26 about 50; Fig. 27 about 300; Fig. 28 about 150; Fig. 29 about 150; Fig. 30 about 200; Figs. 31-42 about 200; Fig. 43 about 60; Fig. 44 about 200; Figs. 56 and 57 natural size.



G F Atkinson ad nat del.

ATKINSON.— LEMANEACEÆ OF THE UNITED STATES.



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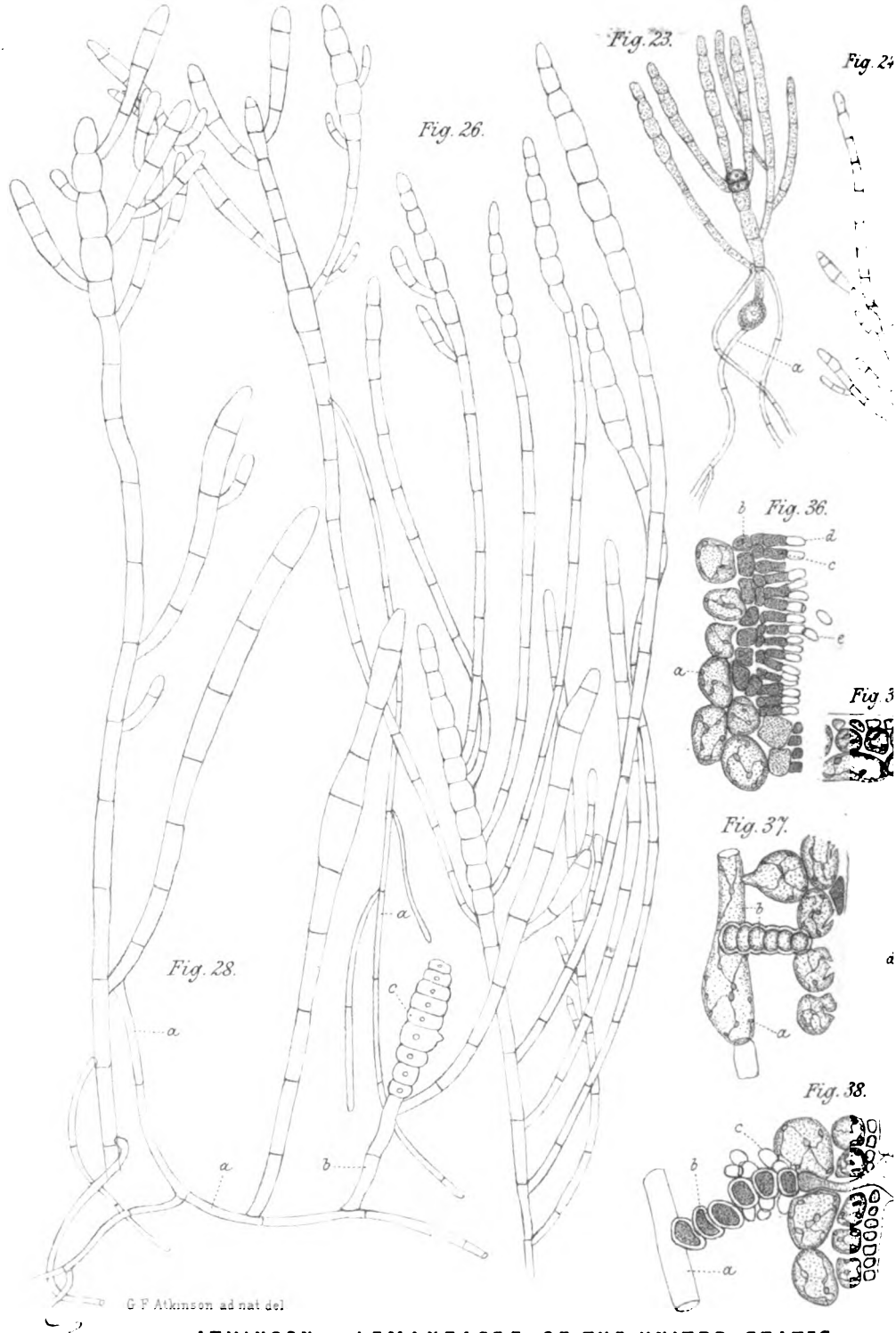
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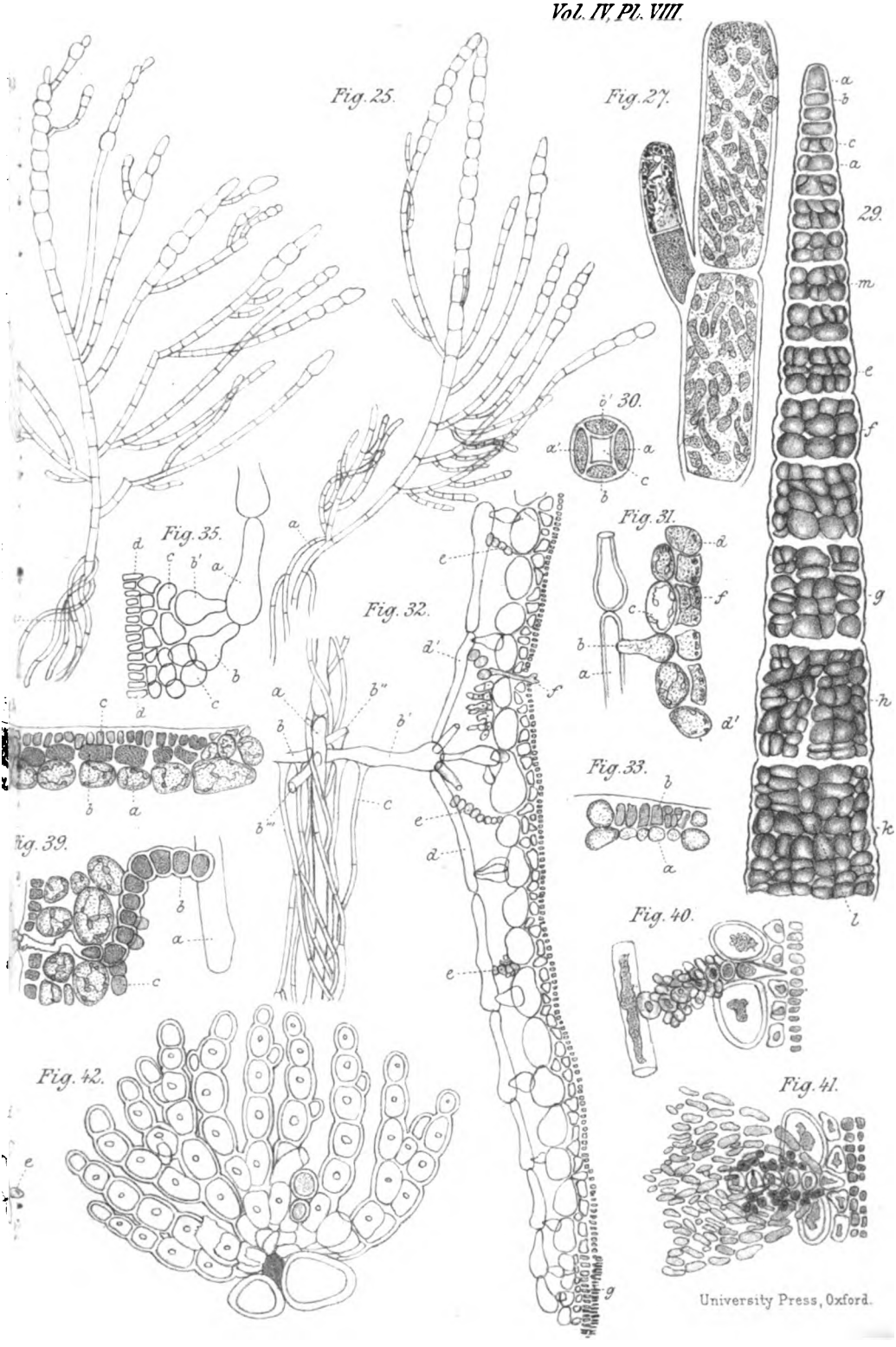

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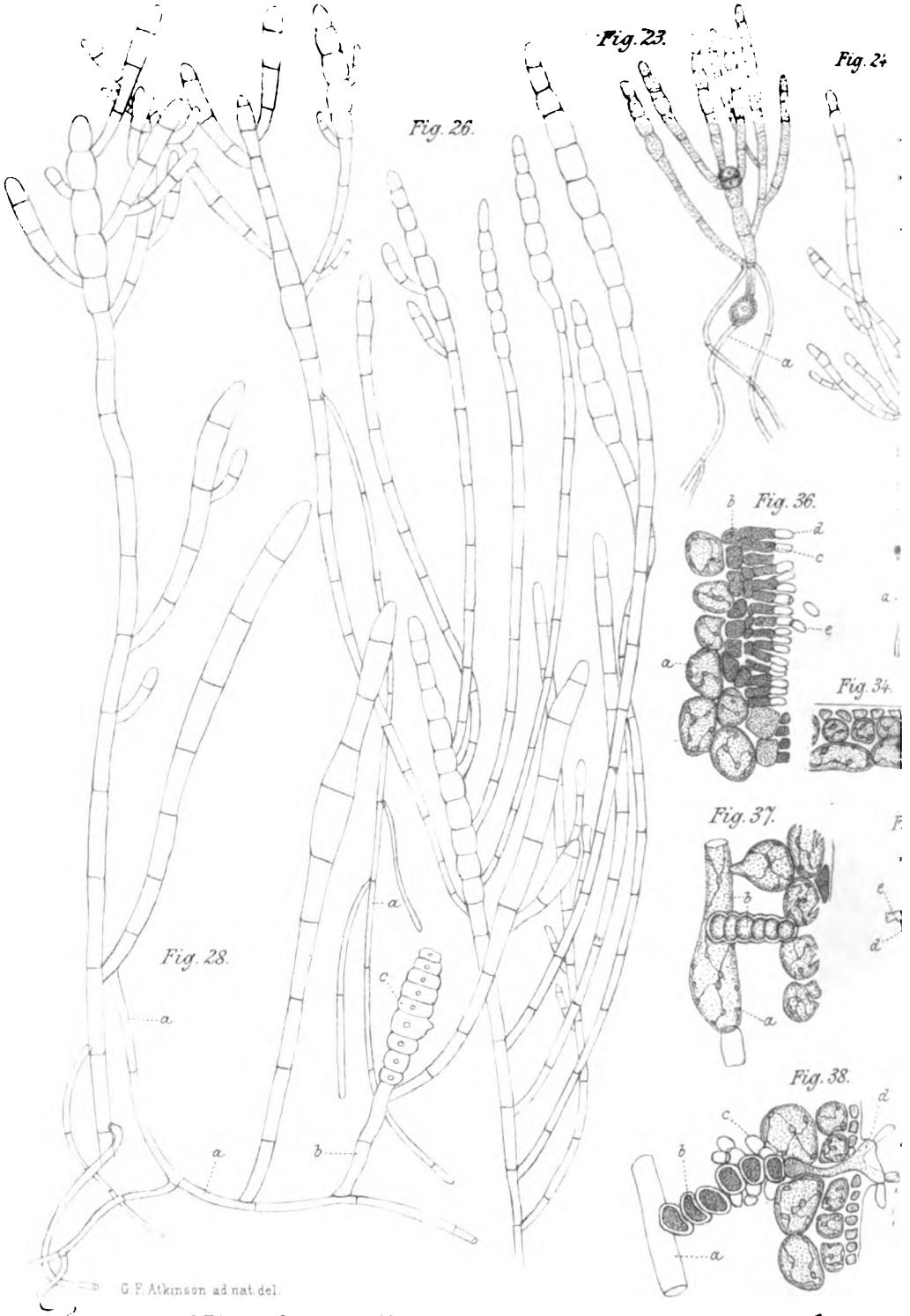
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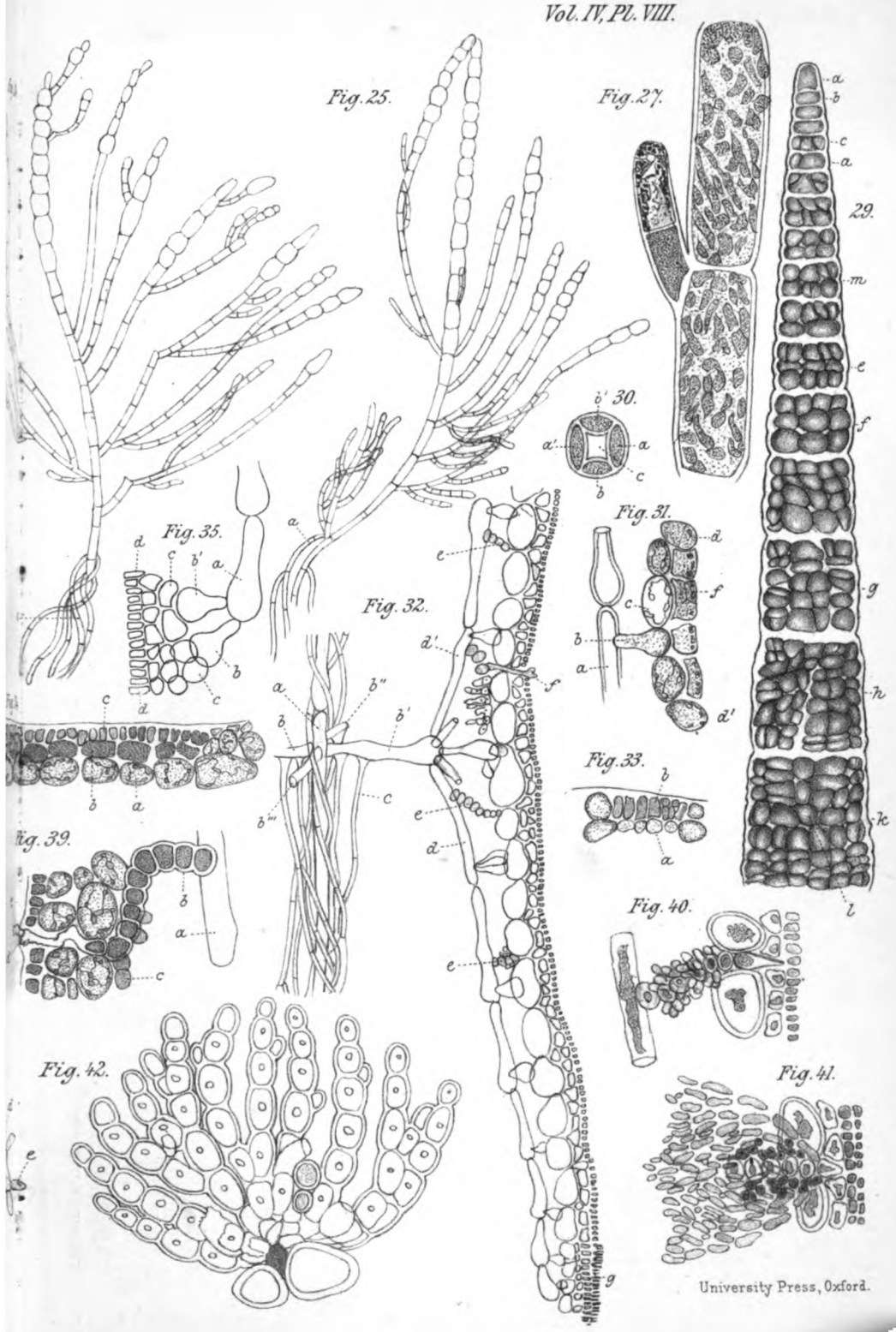

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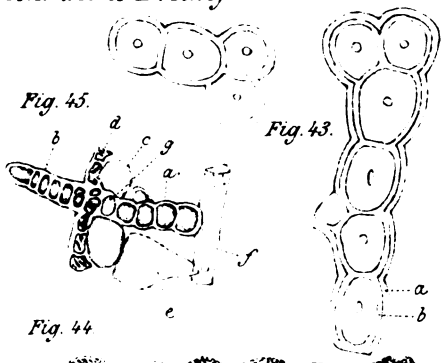

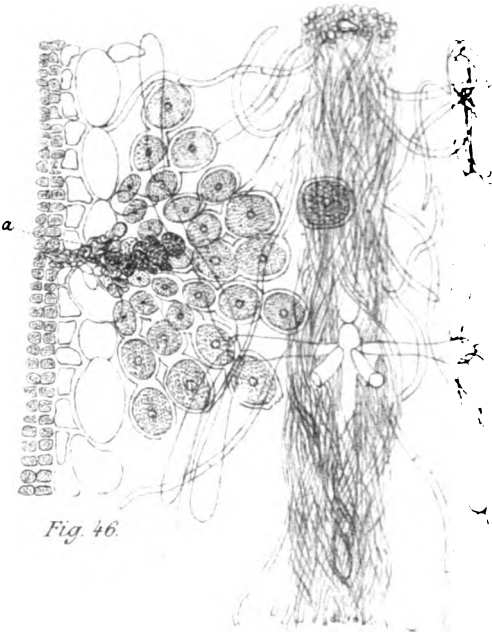

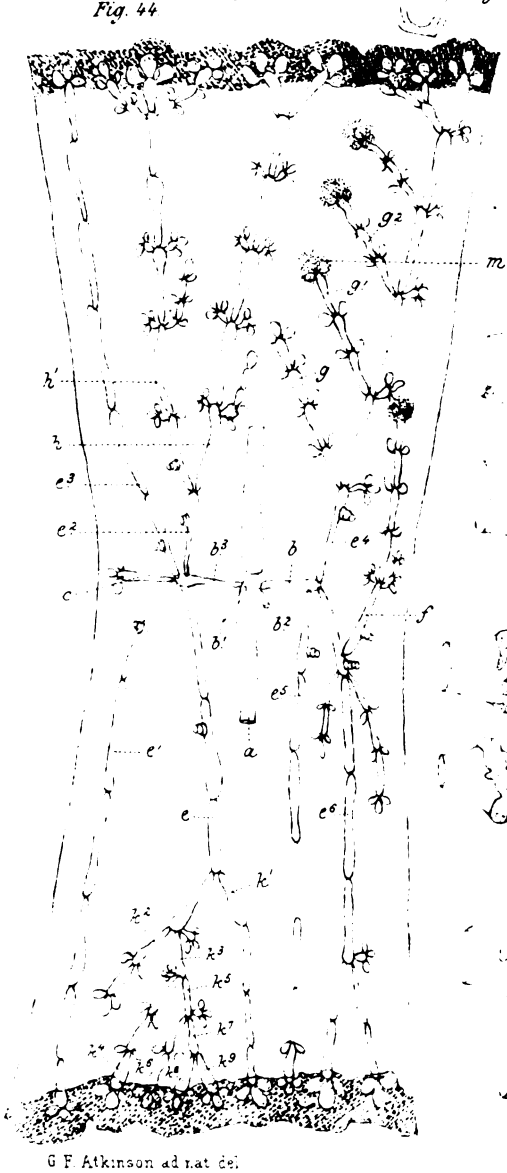

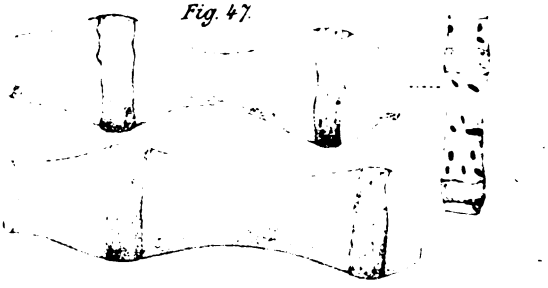

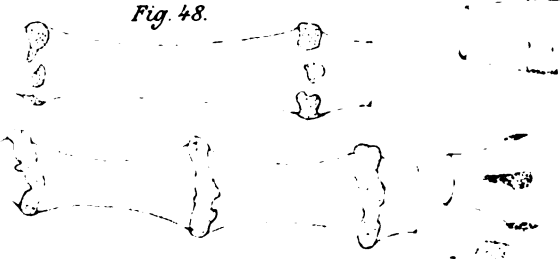

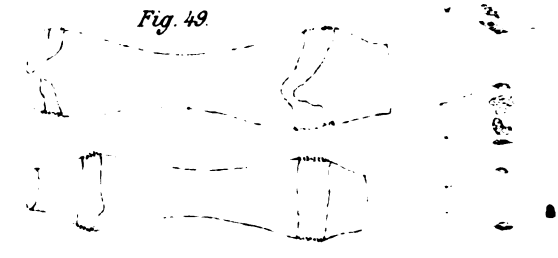

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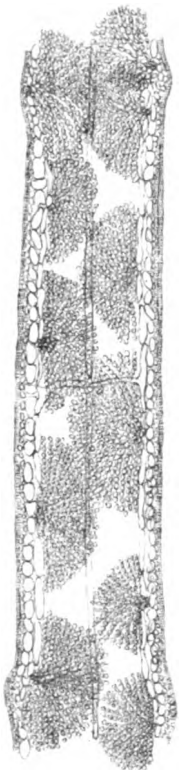

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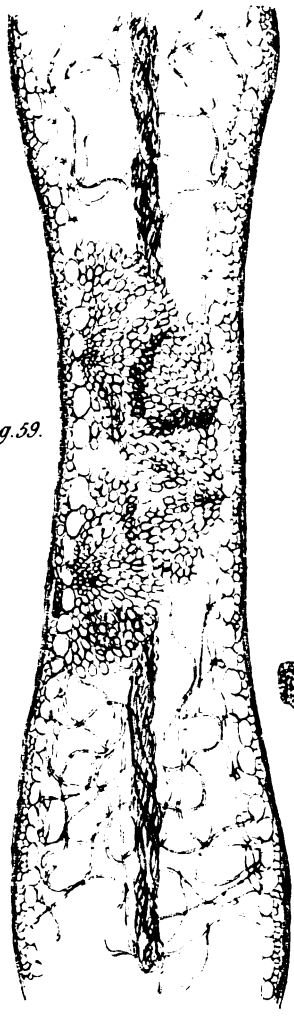

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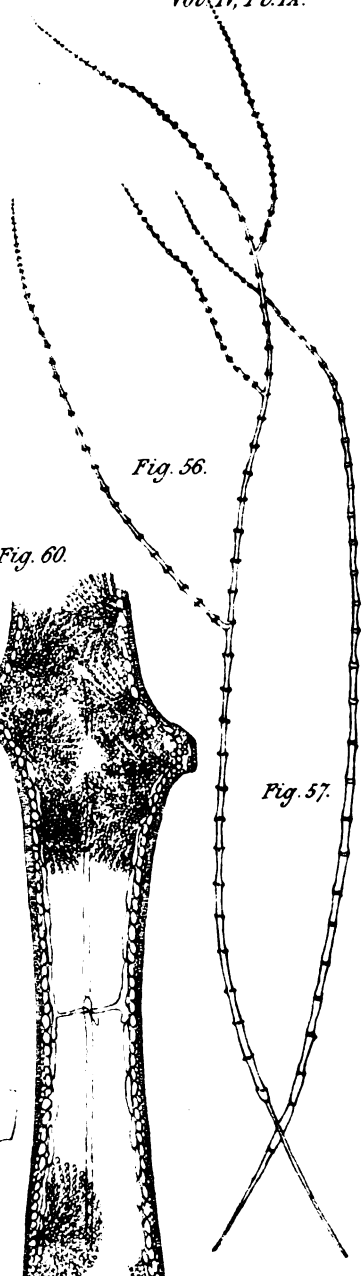

Fig. 56.

Fig. 60.

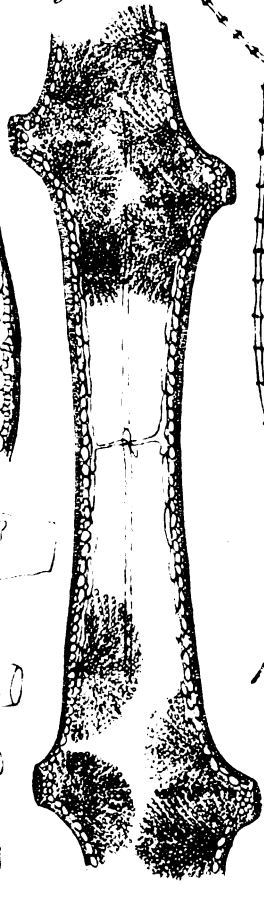

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Fig. 52.

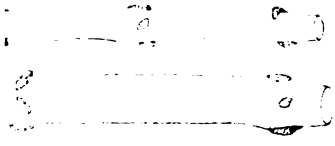

Fig. 50

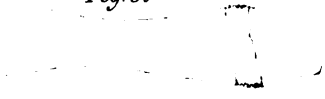

Fig. 53.

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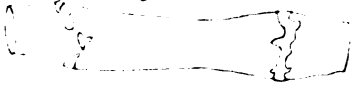

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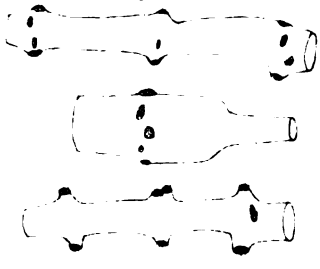

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The Mucilage- and other Glands of the Plumbagineae.

BY

JOHN WILSON, D.Sc.

Lecturer on Botany in the University of St. Andrews.

With Plates X, XI, XII and XIII.

DURING the summer of 1888 my attention was arrested by observing in one of the greenhouses of the Royal Botanic Garden, Edinburgh, that *Statice rosea* had a very copious secretion of mucilage in the axils of its leaves. This species (Fig. 1) is shrubby, with the leaves distichous at the extremities of the branches, the lower portions of which evidently soon become bare. The bases of the petioles are very markedly amplexicaul, the older overlapping the younger to a considerable degree. The fresh discharge of mucilage is of itself usually conspicuous enough to rivet attention, standing as it does high in the axillary spaces of the older leaves (Fig. 1, m^1), or completely enveloping the younger ones (Fig. 1, m). In summer the heat of the sun dries the mucilage, which is then found hanging in white shreds from various points of the leaves and stems. A general coating of hardened secretion may also then be present on the under side of many leaves, and a portion of this mounted dry, being quite transparent, exhibits a faultless reproduction of epidermal cells, stomata and glands (Fig. 2).

It was quite natural to presume the existence of special

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secretory organs, and such were at once seen when preparations of the petiole were made, a series of fine mucilage-glands being found at the base of it. Professor Bayley Balfour, to whom I submitted the preparations, was of opinion that the existence of these glands had not previously been mentioned, and recommended me to prosecute the study of them. Close scrutiny of works likely to contain reference to them has not brought to hand any information on the subject. The matter is of such importance that it is hardly possible they could have been studied, and the records of the observations have failed to find their way into standard botanical literature. Under certain conditions the secretion is so liquid as to be mistaken for water. It is singular enough, however, that the feature should not have been emphasised, seeing that some species in herbaria are found adhering by the secretion, and the operation of drying the specimens might have revealed the condition under remark. Boissier[1], in his monograph of the Plumbagineae, does not touch the question of the glands, although he notices the glutinous condition, e.g. in *Statice lychnidifolia*. Bentham and Hooker[2] are also silent. In only one case have I noticed more direct reference to the secretion (not the glands), viz., by Griffith[3], who describes *Aegialitis rotundifolia* as having a viscous or watery fluid filling the axils.

In two cases the specific name indicates the presence of mucilaginous secretion, viz. *Acantholimon viscidulum* and *Statice gummifera*. The former, which I have not seen, is described by Bunge[4] as having leaves, bracts and rachis viscid.

However remarkable it is that systematists should not have been the means of directing attention to the mucilage-glands, it is much more remarkable that observers who have made the

[1] Boissier, De Candolle's Prodromus, Part 12, 1848.

[2] Genera Plantarum, vol. ii, Part 2, 1876.

[3] *Notulae ad Plantas Asiaticas* (Posthumous Papers of the late William Griffith, F.L.S.). Calcutta, 1854.

[4] Bunge, Die Gattung *Acantholimon*, Mémoires de l'Acad. de St. Pétersbourg, sér. 7, tome xviii, 1872.

leaves of Plumbagineae a special study should have missed them, while the more widely distributed but smaller glands, about to be referred to, were noted.

The study of the vegetative organs of any member of the family is not proceeded with far when one finds, studded over the leaves, stem, &c., sunk oval or circular glands with characteristically cruciform diametrical partitions (Fig. 5, i). According to Maury[1] these glands were discovered by Licopoli[2] in 1865. In 1830, however, Braconnot[3], when making analyses of the mineral substances secreted by the Plumbagineae, suggested the existence of special organs of secretion, and, in 1856, Mettenius[4] described and figured the glands in question. The latter referred to the occurrence of these organs in *Armeria*, *Statice*, *Goniolimon*, *Limoniastrum* and *Plumbago*, taking special notice of their chalk-secreting function. He believed them to be composed of four cells, although one figure, that of a gland on the under side of the leaf of *Plumbago europaea* (Taf. XXVIII, Fig. 26), shows eight cells—a condition to be afterwards spoken of.

Maury's memoir (Organisation des Plombaginacées) is a valuable contribution to the study of the life-history of the order, dealing with it in all aspects,—structure, affinity, classification and distribution. He examined very many species, and noticed in them all the minute glands referred to above. These he terms *Organes de Licopoli.*

In 1866 Licopoli thought that these organs were similar to the stomata of *Marchantia* in function, but in 1878[5] he changed his opinion of their nature and named them calciferous glands. In the later paper he makes mention of nine species representing *Plumbago*, *Limoniastrum* and *Statice.* It must be admitted that his figures illustrative of these are

[1] Maury, Ann. Sci. Nat., sér. 7, tome iv, 1886.
[2] Licopoli, Annali dell' Acad. degli aspirante naturalisti de Napoli, 1866.
[3] Braconnot, An. de Chimie et Phys., tome lxiii, 1836, p. 373.
[4] Mettenius, Filices Horti Botanici Lipsiensis, 1856, p. 10.
[5] Licopoli, Gli stomi e le glandole delle piante. Atti della R. Academia delle Scienze Fisiche e Matimatiche, vol. viii. 1879.

often diagrammatic, or else drawn from objects altered during preparation.

It is only in certain species or under certain conditions that the glands under discussion secrete chalk-scales; but in all cases their normal structure is the same. For the sake of convenience I shall term them henceforth *Mettenian glands* (glands of Mettenius).

De Bary[1] describes these organs as composed of 'eight cells arising from one epidermal cell, which appears in surface view rounded and quadratic. This is divided by two walls, perpendicular to the surface and to one another, into four; each of the latter again divides by a perpendicular wall into two; one very small one forming the inner angle, and one being peripheral. The cells of these groups are thin-walled, and contain dense finely granular protoplasm. Their outer walls lie in many species at the surface; in others, especially thick-skinned species, they form the base of hollow depressions, e.g. *Statice alata*, *S. purpurea*, *S. monopetala*.'

Maury[2] presumes that Licopoli's investigations were unknown to De Bary, and, adhering to the description by the former as correct, puts the following as emphatically his own opinion of the structure of the glands:—'La cellule-mère se divise tout simplement en quatre et chacune de ces cellules est sécrétrice: leur produit s'amasse entre elles dans l'espace intercellulaire, et il est rejeté dehors par suite de la tension des cellules qui restent toujours unies à leur partie inférieure.'

Volkens[3] made observations on 75 species, which he tabulates according as they secrete much, little, or no calcium carbonate. He accepts De Bary's description of the chalk-glands, and points out a feature the latter seems to have missed, viz., accessory cells (*Nebenzellen*) surrounding the glands in (at least) twelve Statices, Armerias and Plumbagos which he specifies.

[1] De Bary, Vergleich. Anat. d. Vegetationsorgane d. Phanerogamen und Farne, 1877 (Eng. ed. 1884, p. 107).

[2] Maury, loc. cit., p. 58.

[3] Volkens, Ueber die Kalkdrüsen der Plumbagineen, Berichte d. d. bot. Ges., Jahrg. II, 1884, Heft 7.

Woronin[1] confines his researches chiefly to the leaves of *Statice monopetala* (*Limoniastrum monopetalum*), but touches also on *S. latifolia* and *S. sareptana*. He, as well as Volkens, follows De Bary's interpretation of the glands, and both make no mention of Licopoli's labours.

Martinet[2] refers to the well-known stalked external glands, and also to the minute internal glands, on the calyx of *Plumbago*; and Maury[3] describes the development of the former.

It may be remarked here that Vines[4] is misleading in the following statement:—'Similar scales [calcium carbonate] occur also on the leaves and herbaceous stems of various Plumbaginaceous plants. . . . In these cases no glands like that described [water-gland] are present; it is therefore to be concluded that *the epidermal cells themselves* excrete the calcium carbonate.'

The following is an alphabetical list of the identified species studied in connection with the present paper, the arrangement of the genera being that given by Bentham and Hooker[5].

Tribe I. STATICEAE.

1. *Aegialitis annulata*, R. Br.

2. *Acantholimon acerosum*, Boiss., *A. armenium*, Boiss., *A. bracteatum*, Boiss., *A. cabulicum*, Boiss., *A. calocephalum*, Ait. et Hems., *A. Calverti*, Boiss., *A. distachyum*, Bois., *A. Echinus*, L. (*A. androsaceum*, Boiss.), *A. glumaceum*, Boiss., *A. Pinardi*, Boiss., *A. roseum*, Boiss., *A. Stocksii*, Boiss., *A. tenuiflorum*, Boiss., *A. tibeticum*, Hook. fil. et Thoms., *A. venustum*, Boiss.

3. *Statice altaica*, Hort., *S. arborescens*. Brouss., *S. articulata*, Lois., *S. auriculaefolia*, Vahl, *S. axillaris*, Forsk., *S. Bonduellii*, Lestib., *S. Bourgaei*, Webb, *S. cabulica*, Boiss., *S.*

[1] Woronin, Notiz über die Structur der Blätter von *Statice monopetala*, L. Bot. Zeit., Jahrg. xliii, 1885.

[2] Martinet, Organes de Sécrétion des Végétaux, Ann. Sci. Nat., sér. 5, tome xiv, 1872, pp. 167, 195.

[3] Maury, loc. cit., p. 55.

[4] Lectures on the Physiology of Plants, p. 246. Cambridge, 1886.

[5] Genera Plantarum, vol. ii, Part II, p. 624.

Caspia, Willd., *S. chrysocomia*, Kar. et Kir., *S. cordata*, Guss., *S. cylindrifolia*, Forsk., *S. Dodartii*, Gir., *S. duriuscula*, Gir., *S. echioides*, L., *S. eximia*, Schrenk, *S. fruticans*, Webb, *S. globulariaefolia*, Desf., *S. Gougetiana*, Gir., *S. graeca*, Boiss., *S. gummifera*, Dur., *S. Holfordii*, Hort., *S. imbricata*, Webb, *S. jovi-barba*, Webb, *S. leptostachya*, Boiss., *S. Limonium*, L., *S. lychnidifolia*, Gir., *S. macrophylla*, Brouss., *S. macrorrhabdos*, Boiss., *S. minuta*, L., *S. pectinata*, Ait., *S. perfoliata*, C. A. Meyer, *S. puberula*, Webb, *S. pubescens*, DC., *S. purpurata*, L., *S. pruinosa*, L., *S. rosea*, Sm., *S. sareptana*, Becker, *S. sinensis*, Gir., *S. sinuata*, L., *S. spicata*, Willd., *S. Suworowi*, Regel, *S. tatarica*, L., *S. Thouini*, Viv., *S. tomentella*, Boiss., *S. virgata*, Willd.

4. *Armeria allioides*, Boiss., *A. canescens*, Boiss., *A. cephalosa*, Boiss., *A. cephalotes* var. *bracteata*, *A. chilensis*, Boiss., *A. elongata*, Hoffm., *A. fasciculata*, Willd., *A. filicaulis*, Boiss., *A. Halleri*, Wallr., *A. latifolia*, Willd., *A. longiaristata*, Boiss. et Reut., *A. plantaginea*, Willd., *A. siberica*, Turcz., *A. splendens*, Boiss., *A. vulgaris*, Willd., *A. vulgaris* var. *californica*.

5. *Limoniastrum Guyonianum*, Boiss., *L. monopetalum*, Boiss.

Tribe II. PLUMBAGEAE.

6. *Plumbago capensis*, Thunb., *P. europaea*, L., *P. micrantha*, Ledeb., *P. pulchella*, Boiss., *P. rosea*, L., *P. scandens*, L., *P. zeylanica*, L.

7. *Ceratostigma Griffithsii*, Clarke, *C. abyssinica*, Ascher, *C. plumbaginoides*, Bunge.

8. *Vogelia africana*, Lam., *V. indica*, Wight et Gib., *V. indica* var. *socotrana*, Balf. fil., *V. pendula*, Balf. fil.

METTENIAN GLANDS.

It is desirable at this stage to give the details of some observations on the above organs. As to the typical gland described by Mettenius, Licopoli, Maury and De Bary, I am convinced that the account of the structure given by De Bary

is the correct one. I have been unable to see the central cavity figured by Maury[1]; and it is not easy to conceive of the secretion being pressed out *en masse* as he avers.

It is usual to find in each of the four inner cells a refractive body which is probably a nucleus (Fig. 4, v.) The diameter of the orifice of the gland is ·1 mm., and the cells bounding it are usually the same as those of the general epidermis. Some striking departures from the normal condition are met with. On the flower-stalk of *Statice pruinosa* the epidermal cells around the glands tend to become enlarged so as to form conspicuous rosettes. Side by side can be seen examples of all the transitional stages from the typical gland to that encircled by a mass ·5 mm. in diameter, formed of three or more tiers of radiating cells (Fig. 4, i, ii, iii, iv, v).

Similarly situated cells in *Statice chrysocomia* undergo modification of a different character, the greatest development taking place on the under side, leading, in the ultimate case, to the gland being elevated on a bracket-like mass, ·26 mm. in diameter, with its orifice directed upwards at right angles to the stem (Fig. 5, i, ii, iii, iv, v). In this species and in *S. pruinosa* the greatest amount of modification is found at the upper portion of the rachis. No chalk-scales were found in connection with these glands, but they most likely occur in plants grown under certain conditions. In both these species the glands of the lamina are of the ordinary type.

On both sides of the leaf of *Statice rosea* forms somewhat similar to those just described appear. A fully developed example, ·4 mm. across (Fig. 6), is flanked on the lower side by a large cushion of stout-walled cells which forms a resting-place for a nodule of calcium carbonate of corresponding outline. All stages of the development of the cushion may be observed. Sometimes the orifice of the gland is over-arched by enlarged cells, even when there are few. The gland is often borne outward and upward, as in *S. chrysocomia*, until its surface is perpendicular to the leaf-blade. Although appearances justify the suggestion being made, it is not likely

[1] Maury, loc. cit., Pl. 5, Fig. 51.

that the enlarged cells secrete any of the calcium carbonate found resting on them.

On the leaves of *Statice articulata* a somewhat similar condition obtains, the epidermal cells around the glands being often elevated into conical sculptured papillae (Fig. 7). Their arrangement is usually irregular, and they may occur singly or in groups without any connection with the glands.

Statice cordata affords an example in which the glands on the upper side of the leaf are encircled by large cells, the lower of which project more prominently than the upper (Fig. 8).

In the genus *Limoniastrum*, as represented by *L. monopetalum* and *L. Guyonianum*, the Mettenian glands assume a very characteristic form, and function in a very marked manner as chalk-secreting organs. The glands lie sunk at the base of cup-shaped depressions. They have attracted much attention, and have been carefully investigated in *L. monopetalum*, chiefly and most recently by Woronin[1]. The leaves of this species (Fig. 9), taken in arid regions, are thickly covered with calcium carbonate. Grown in this country, under glass, the secretion is not so great; nevertheless in summer the whole plant has a peculiar greyish aspect, due to the presence of innumerable dots of calcium carbonate on the stem and both sides of the leaves. When grown under a bell-glass in a high temperature and moist atmosphere the leaves are green and fleshy, the glands then appearing as minute translucent spots. Even under such circumstances, however, the cup-like cavities above the glands are filled with calcium carbonate. Much importance is to be attached to the fact, noted by previous observers, that after the mineral secretion is dissolved away a mucilaginous residuum is left. This indicates clearly enough the mucilage-secreting power of the leaf-glands in general.

The condition of the leaf of *Statice macrorrhabdos* in respect to the quantity of calcium carbonate is striking (Fig. 10).

Hairs, which may be regarded simply as pronounced forms

[1] Woronin, loc. cit.

of papillae, such as occur in *Statice articulata*, etc., are found in connection with the Mettenian glands in a few species of *Statice*. Woronin [1] figures a gland encircled by long tuberculated hairs in *S. sareptana*, and the same feature is figured by Maury [2] in *S. elata*, and in *S. latifolia* by Volkens [3]. In *S. tomentella* one finds glands unprotected by hairs, and also hairs unassociated with glands. The processes encircling the glands in *S. Bourgaei* are usually in groups of four, seldom more. In *S. puberula* (Fig. 17) they are usually from four to six (one only is shown in Fig. 11), and the groups placed so closely together as often to touch one another. The flower-stalk and both surfaces of the leaf of *S. pubescens* are thickly clad with short hairs.

In *Plumbago europaea* Mettenian glands are often carried up some distance on the epidermis of emergences on the margin of the leaf (Fig. 12, *g*). These processes are formed of compacted sclerosed elements, the outer ones being seen at the apex (Fig. 12 *a*) to enclose the central one in a spiral manner. Their base is usually S-shaped, not straight as in the example figured, and tracheides pass up into them about two-thirds their length. In general the glands occur in longitudinal depressions on the stems of Plumbagos, giving rise to a striated appearance when calcium carbonate is secreted. Mettenian glands are present on the leaves and bracts of all, and the sepals of many, of the species of *Acantholimon*, *Statice*, *Armeria*, *Plumbago*, *Ceratostigma*, *Limoniastrum*, and *Vogelia* examined. Their method of development is indicated by De Bary in the paragraph already quoted. On the margins of the leaves of *Plumbago micrantha* they are seen to arise as single cells which become divided into four and sink into the epiderms (Figs. 13, 14). At a point in the middle line on the upper surface of a young leaf of the same species, in active growth, an interesting series of the glands in various conditions of fusion and modification was noticed (Fig. 15).

[1] Woronin, loc. cit., Fig. 10. [2] Maury, loc. cit., Fig. 40.
[3] Volkens, loc. cit., Fig. 10.

Maury has already drawn attention to their occurrence on the cotyledons of *Acantholimon*, *Statice*, *Armeria* and *Plumbago*, even before the light is reached by the germinating seedlings.

Aegialitis is the only genus in the order in which the typical Mettenian glands are not found. In place of these there occur in great numbers, on the leaves (especially the upper surface), stems, bracts and sepals, sunk glands (Fig. 16) displaying greater complexity of structure than is found in the type. They will be returned to in the sequel.

Mucilage-Glands.

Statice.

While in the most marked cases Mettenian glands render their existence very conspicuous by reason of the calcium carbonate secreted on the surface of the lamina of the leaves, the mucilage-glands make their presence equally noticeable by the large quantity of transparent, colourless, viscous secretion poured forth at the base of the petioles. As already remarked, the latter feature specially characterises *Statice rosea*. It is equally noteworthy in the section represented by *S. fruticans* (Fig. 3). This species, when in full vegetative vigour, has very large leaves radiating in all directions, and the portion of the stem bearing them is then enveloped in a thick layer of mucilage. Its leaf-bases are largely developed for the purpose of support; and they clasp the stem in such a way as to form axillary troughs of considerable capacity (Fig. 3, *tr*). In all species of *Statice* the leaves are more or less amplexicaul. The leaves themselves vary very much in form and size. Besides those already indicated, some distinct examples may be instanced, e. g. *S. puberula* (Fig. 17), *S. axillaris* (Fig. 18), and *S. cylindrifolia* (Fig. 19).

Mucilage-glands were found in the axils of every species of *Statice* examined. In the different cases they vary only in respect of size and number. They are easily seen by

removing a portion of the epidermis from the base of the petiole. Their outline is in general oval. They are most numerous close to the junction of the stem and leaf, and are confined to the latter. In large leaves they may be distributed half an inch above the axil. Sometimes they are restricted to a relatively narrow space. Seldom are they so numerous as to overlap one another as in *Statice macrorrhabdos* (Fig. 20, *o*).

The upper surface displays the appearance of being formed of very numerous extremely thin-walled cells; the base is composed of relatively few stout-walled ones (Fig. 20, *c*, *b*). A vertical section of a fully developed gland (Fig. 21) shows that the secreting cells are prismatic, columnar or conical. They radiate from the basal cells, and may or may not be divided by a few transverse septa. The contents are finely granular. Now and again, more especially in young glands, nuclei may be seen. After staining, a vacuolated appearance, due probably to the accumulation of mucilage, particularly towards the periphery of the gland, can be detected. As to the method of discharge, it seems to be accomplished by simple exudation, not by gradual accumulation of mucilage under, and subsequent rupture of, the cell-membrane. The mucilage is evidently highly hygroscopic, and is thus often so fluid as to be easily mistaken for water. On the other hand, it can be dried to form brittle, delicate sheets and shreds. In alcohol it hardens as an opaque white substance of considerable toughness. It is innocuous; and *Cocci* are attracted to it, as they are to the secretion in the axils of the stipules of *Cinchona*[1].

In three cases, viz., in adult *Statice sareptana* and *S. Caspia*, and a rather young *S. Thouini*, a few mucilage-glands have been found elevated on conical epidermal projections (Fig. 22), recalling, in some measure, the calycine glands of *Plumbago*.

[1] See Lawson, 'Cinchonaceous Glands,' Trans. Bot. Soc., vol. v. Part I, 1856, p. 3.

Examples of species possessing very numerous and large glands are:—*Statice rosea*, *S. fruticans*, *S. macrorrhabdos*, *S. macrophylla*, *S. tatarica*, *S. gummifera*, *S. jovi-barba*, etc. In *S. axillaris*, *S. pectinata* and *S. cylindrifolia* they are large but few.

Mucilage-glands appear in the axils of the bracts of some species, e.g. *S. eximia* and *S. pectinata*, and in the axils of the leaves of small vegetative shoots on the rachis of *S. Gougetiana*. In most herbaceous species of *Statice* the mucilage, if not welling up visibly, can be seen by pushing the leaves away a little from the axis.

Armeria.

Mucilage-glands appear in the axils of all the species of *Armeria* enumerated above. Specimens of *A. vulgaris* (*A. maritima*) were examined from Ben Ledi, Cairngorm, and other alpine stations, as well as from different maritime ones. The conditions of growth obtaining on the summit of a mountain are very different from those in the mud-flats of an estuary, but no differentiation indicative of a particular habitat is noticeable in the glands. A portion of a sea-pink, from the salt-marshes of the river Eden, in Fife, is figured, as seen in the winter season (Fig. 23). It is so deeply placed in the damp salt soil that nothing but the rosettes of leaves are visible. These terminate branches which are united to form considerable patches of the plant. The 'collars' and upper regions of the branches are protected by a thick felt formed of the bases of dead leaves, in the axils of which the remains of glands occur. A nucleus and nucleolus were noticed in a young fresh secreting cell. The mucilage-glands are of the same type as those in *Statice*; but the basal cells are comparatively few in number. They are scattered over a narrow area close to the axils. The petiole is distinctly amplexicaul. The axillary glands of *Armeria vulgaris*, var. *californica*, are relatively few and fine. In *A. chilensis*, as grown from seed at Kew, the great majority of the glands have only four basal

cells (Fig. 25). The habit of the seedling and the method of attachment of the leaf are illustrative (Fig. 24).

Mucilage-glands proper have not been satisfactorily determined in the axils of the bracts and bracteoles. A very remarkable series, however, occurs on the inner face of the tubular involucral sheath, so diagnostic of the genus. The species hitherto found to display this feature are *A. vulgaris*, *A. longiaristata*, *A. Halleri*, *A. cephalosa*, *A. plantaginea*, *A. cephalotes*, var. *bracteata*, and *A. splendens*. It may be conjectured that the condition in one species will, with but slight modification, hold good for all species of *Armeria*. As in the case of the leaf, the glands congregate closely to and are restricted to the base of this organ (Fig. 26, *c*), and there is no difference in their structure, except that the base may be oftener formed of more cells than four. Mettenian glands are numerous on the epidermis of the inside and outside of the sheath, and also among the short hairs on the rachis under it. If one accepts the hypothesis that the reverted sheath originates by peltation of the bracts, the occurrence of these mucilage-glands is not difficult to explain. They may be thus regarded simply as axillary glands. *Armeria cephalotes*, var. *bracteata* [1], displays a notable abnormality, the place of the outer bracts being taken by leaves, while the involucral sheath still remains [2]. Mucilage-glands occur in the axils of these foliar organs—an interesting fact, corroborative of the hypothesis just stated.

LIMONIASTRUM.

The leaves of *Limoniastrum monopetalum* (Fig. 9) clasp the stem closely and completely, forming a small crescentic trough in the axil, where, in the living specimen, the secretion is easily seen. Mucilage-glands are present there in considerable numbers. They are characterised by the basal cells being larger than usual. In the present connection *L. Guyoni-*

[1] Gardeners' Chronicle, vol. xx, 1883, Fig. 34, p. 213.

[2] See also *Armeria plantaginea*, Sowerby's English Botany, 3rd ed., vol. vii, p. 159, Pl. MCLIV.

anum does not differ to any appreciable degree from the foregoing.

AEGIALITIS.

Aegialitis annulata, a leathery-leaved undershrub from the sea-coast of Australia, is one of the most remarkable species of the order. The extremely mucilaginous nature of the plant may be understood from its gummy appearance in herbaria, where it is alone to be met with in this country. The petiole is of considerable length, and amplexicaul to a great degree. The inspection of a piece of epidermis from its base at once reminds one of the 'digestive surface' of *Nepenthes*. The similarity is only superficial, for in *Nepenthes* the glands lie at the termination of vascular traces, whereas the mucilage-glands of *Aegialitis* and all other *Plumbagineae* have no such connection. The largest glands in *Aegialitis* are found in the axils of the leaves (Fig. 27), but those on the laminae (Fig. 16), bracts, and sepals, though smaller, are of the same character. The secreting cells are very numerous, and lie in an oval or circular depression, bounded by regularly arranged cells (Figs. 16, 27, *x*), and their function in all cases appears to be mucilage-secreting. The partitions of the epidermal cells forming the rim of the depression correspond with walls of the basal cells; but between these there are many basal walls (Fig. 16, *b*) which do not reach above the sub-epidermal tissue.

VOGELIA.

A very few mucilage-glands were detected in the axil of a small leaf of *Vogelia indica*, var. *socotrana* (Fig. 28). In structure they agree essentially with those in *Aegialitis*, being sunk, and having the same well-defined boundary. Here it is seen to slope gradually up to the summit (Fig. 28, *x*), a little above the surrounding leaf-surface, then suddenly dip downward till it meets the secreting cells. Axillary glands were not met with in either *V. indica*, *V. africana*, or *V. pendula*. Probably renewed search would lead to their discovery in all

three species. At all events one ought to expect them to be present in *V. indica*, when a variety of it possesses them. Professor Bayley Balfour calls attention to the occurrence of glands on the inner face of the calyx of *V. pendula*[1]. They are scattered over the median area of the sepals (Fig. 29, *gl*), and are either sessile or elevated on small pedicels. The base of the glands is usually four-celled (Fig. 30, *b*); often it is two-celled. The secretory cells are numerous, and very thin-walled. They closely resemble the sessile glands on the sepals of *Plumbago coccinea* and *P. capensis*, to be afterwards described.

Ceratostigma.

Small but very numerous multicellular mucilage-glands occur in the axils of the leaves of *Ceratostigma abyssinica*. Similar organs were not positively determined in *C. Griffithsii*; but better material would probably disclose them. *C. plumbaginoides* seems to be without them. Mettenian glands alone occur on both faces of the calyx, along with sclerosed dendritic hairs common in the genus.

Acantholimon.

The leaves of this genus are ordinarily aciculate, the bases being membranous, amplexicaul, and closely pressed to the stem some distance above the line of origin. In very few cases only do glands appear on the petiolar sheath, worthy of the term mucilage-gland as applied hitherto. One portrayed (Fig. 31) from the axil of *Acantholimon cabulicum*, although only ·17 mm. in diameter, must be regarded as such. In *A. venustum* a few multicellular glands projecting prominently above the surface of the epidermis were found. One measuring ·29 mm. and another ·26 mm. in diameter, could not be otherwise designated than mucilage-glands proper. Similar glands were seen in *A. tenuifolium*, *A. Pinardi*, and *A. Calverti*. In *A. calocephalum*, *A. armenium*, *A. tibeticum*

[1] Balfour, Botany of Socotra, Trans. Roy. Soc. Edinburgh, vol. xxxi, 1888, p. 151.

and *A. glumaceum* there were found in the same situation oval multicellular glands only a little larger than the Mettenian. To these the name 'intermediate' may be appropriately given. In the remaining species of *Acantholimon* examined even these were not met with. The genus would thus seem to be characterised by the almost universal absence of mucilage-glands strictly so-called. At best there is but a distant approach to the condition exemplified by Statices and Armerias. What are here styled intermediate glands occur abundantly in all genera. They will be further treated of below.

PLUMBAGO.

Plumbago rosea possesses a few mucilage-glands in the leaf-axils, the largest being ·38 mm. in diameter. Glands of a similar size are found in *P. capensis*. In the latter species the base of the leaf is very narrow, and one hardly expects to find mucilage-glands there. The search for them is not always successful, and it is possible that they are not present in the axils of all the leaves. Hair-like prominences also occur in the axils of this species. In *P. zeylanica* mucilage-glands of the same size as those in the above species occur. A large number were seen clustered in the axil of a young leaf, a somewhat small example from which is figured to illustrate the relative size of the basal and secretory cells (Fig. 32, *b*, *c*). Distinct mucilage-glands exist in the axils of the bracts as well as of the leaves of *P. scandens*. They have not been hitherto discovered in *P. pulchella*, *P. europaea*, or *P. micrantha*. Intermediate glands are conspicuous in *P. europaea* (Fig. 33). They exhibit the accessory cells (*ac*) which Volkens[1] found characteristic of the Mettenian glands in this and other *Plumbagineae*. *P. micrantha*, an annual species, presents the great peculiarity of bearing on the margins of its leaves and auricles, glands which are either sessile, or elevated on conical epidermal processes (Figs, 34, 35). They are present round the entire margins, and

[1] Volkens, loc. cit.

are less numerous at the apex than at the base. The stout basal cells are often more than four in number (Fig. 34, *b*), and the glandular portion ranges from ·12 mm. to ·18 mm. across.

The stalked glands on the exterior of the calyx of cultivated species, e.g. *P. capensis* and *P. rosea* (Fig. 36), are very familiar objects. They have been studied by Maury[1], Martinet[2], and others. The extreme viscidity of the mucilaginous secretion has been remarked by many authors. In *P. zeylanica* the entire rachis is thickly studded with active glands like the calycine ones, but more minute. The glands of *P. rosea* are spherical, bright-red, and formed of very numerous polygonal cells. When fully developed they are very opaque, and their whole structure remarkably tough. The stalk penetrates a considerable distance into the fully-formed head, so as to make the base of the gland dome-shaped or conical. This condition is very pronounced in *P. scandens* (Fig. 37). Spiral vessels pass up a greater or less distance into the stalks. Seeing, however, that vessels are found penetrating simple emergences, e.g. in *Ceratostigma*, etc., no special significance attaches to them in connection with the glands. Younger and smaller external glands are fairly translucent. The stalks of almost sessile glands are composed of a few comparatively large cells (Figs. 38). Minute glands (·12 mm. in diameter) nearly sessile were found, having their base formed of four cells.

Maury has figured[3] sessile glands on the inner face of the sepals of *P. capensis*. The same occur also in *P. scandens* (Fig. 68), *P. europaea*, *P. zeylanica* (Figs. 40, 41), and *P. rosea* (Fig. 70). Their basal cells are usually four in number, but very often two (*P. rosea*). Sometimes the basal cells are deep as in *P. scandens* (Fig. 68, *b*), and in all cases they support numerous very thin-walled secreting cells. These glands are evidently homologous with those similarly situated in *Vogelia*. Their homology with the stalked glands on the exterior of the calyx, traced through the smaller and almost sessile ones there, cannot be doubted. Further, the sessile glands do not

[1] Maury, loc. cit., p. 55. [2] Martinet, loc. cit., p. 195.
[3] Loc. cit. (Pl. V, fig. 62).

offer any point of material distinction from normal mucilage-glands of the leaves.

Observations on Seedlings.

The following species were grown from seed and studied in the early stages:—*Armeria vulgaris*, *A. plantaginea*, *A. latifolia*, *Statice spicata*, *S. sinuata*, *S. Thouini*, *S. Bonduellii*, *S. tatarica*, *S. duriuscula*, *S. globulariaefolia*, *S. purpurata*, *S. virgata*, *S. sinensis*, *S. fruticans*, *S. perfoliata*, *S. Dodartii*, *Plumbago zeylanica*.

Armeria.

The inspection of the axils of the cotyledons of *Armeria vulgaris* disclosed the very interesting fact that mucilage-glands are present there (Fig. 42, *mg*). In the first case the cotyledons were a quarter of an inch above the level of the ground. The bases of the cotyledons are markedly connate, forming a deep cup at the bottom of which the mucilage-glands nestle. The basal cells are normally in quadrants, and the secreting surface is soon relatively large (Fig. 43, *c*). The Mettenian glands are present on the cotyledons (Fig. 42, *g*), a fact noted by Maury, who, however, does not mention the existence of the axillary glands.

The basal cells of some of the glands of a seedling appearing above ground presented irregularity of division (Figs. 44, 45). A still younger seedling, having the cotyledons just separating from each other, bore many mucilage-glands, the youngest of which exhibited nuclei and nucleoli (Fig. 46, *n*). Among the few glands of a specimen still under ground (Fig. 47) one displayed more regular geometric arrangement of the secreting cells than usual (Fig. 48). A germinating seedling (Fig. 49), cautiously removed from the seed-coats, exhibited a number of Mettenian glands and a few (six ?) mucilage-glands. Of two of the latter (Fig. 50), the smaller measured ·05 mm. in diameter. It presented the appearance of a single cell divided into four by exceedingly delicate partitions. The larger gland was very peculiar in having its

base simply bisected. The extent of the secreting surface, which was formed of a few very delicate cells, is indicated by a dotted circle (*c*).

The walls of the basal cells of older mucilage-glands, when acted on by a solution of caustic potash, retain distinction of contour but are flanked by broad mucilaginous boundaries internally (Figs. 61, 62). The same treatment causes great swelling of the walls of the secreting cells (Fig. 52), and when these are set free by rupture consequent on pressure they each appear as a mass of granular protoplasm, surrounded by an extremely translucent hyaline coat (Fig. 53).

A seedling in which the cotyledons were abnormally fused (Fig. 51) bore many mucilage-glands. Another having the bases of the cotyledons still enclosed in the seed-coats, and the radicle projecting about one eighth of an inch, displayed eight or nine mucilage-glands. An embryo was picked from the seed before it showed any sign of pushing out the radicle. The cotyledons were still light greenish-yellow (etiolated), and were easily separable after boiling. No glands were yet developed.

An example of *A. plantaginea* with the radicle just appearing beyond the investments of the seed (Figs. 54, 55) had no mucilage-glands, but a few of the Mettenian were present. From this it may be inferred that the latter appear as a rule on the cotyledons a little while before the former. In some cases, however, they seem to be simultaneous in appearance.

A seedling of *A. latifolia*, when removed from the seed (Figs. 56, 57), allowed of the cotyledons being readily separated from each other. On one of them a Mettenian gland in a very early stage of development was noticed (Fig. 58, *g*). It was not so large as many of the neighbouring epidermal cells, but distinguished from them by its refractive character and its cross-divisions. The outline of this gland at first is thus that of an ordinary epidermal cell. Very soon a circular form is assumed, and while still very young the inner concentric walls appear. The refractive specks (nuclei ?) are commonly visible in the inner cells (Fig. 59, *n*). Other two examples of the same species, slightly younger than the above,

with their cotyledons still held firmly together by the seed-coats, had respectively five and six mucilage-glands in their axils. The depth of the gland-bearing cavity formed by the fused bases of the cotyledons is very considerable by the time the first leaves appear (Fig. 60, *ms*).

STATICE.

A seedling *Statice duriuscula* not yet quite liberated from the seed-coats had nine mucilage-glands. Two of these showed points of interest, the glandular cap being divided into four by cross walls evidently continuous throughout its entire depth, and also having an inner circular division (Fig. 69). Both features are characteristic of Mettenian glands. Two seedlings of *S. spicata*, about to burst through the soil, but still with their cotyledons close together and curved over to one side, possessed seven or eight mucilage-glands. Many glands in an example of *S. tatarica* of the same age showed a multiplicity of basal cells (Fig. 64). In another, above ground, with the cotyledons commencing to separate, very many Mettenian glands were found possessing a similar condition of the basal cells. A like irregularity occurred in mucilage-glands of *S. Thouini*, which species displayed well the arrangement of the glands at the base of the cotyledons whether in vertical (Figs. 65, 66) or in transverse section (Fig. 67 *mg*). Mettenian glands are clearly seen on the margins of the young cotyledons, e.g. in *S. sinensis*. An advanced seedling of *S. sinuata* having one leaf about half an inch in length, and the other an eighth of an inch, had five mucilage-glands in the axil of the former and three in the axil of the latter. The other species of *Statice* examined do not call for special remark.

In no case were Mettenian glands seen on the hypocotyledonary axis of *Armeria* or *Statice*.

PLUMBAGO.

The cotyledons of *Plumbago zeylanica* (Fig. 60, *a*) are very distinct from those of *Statice* and *Armeria* in size, form

colour and texture. The swelling which indicates the existence of the cavity at the base of the cotyledons of these genera is wanting in the *Plumbago* studied. Examples of different ages were closely examined, revealing the fact that no mucilage-glands exist at the base of the cotyledons. Mettenian glands are as usual present on the cotyledons, and they likewise occur sparingly on the hypocotyledonary axis. A seedling which had the plumule destroyed at an early stage continued to vegetate by its cotyledons alone, which persisted for many months. They were ultimately $1\frac{5}{8}$ in. long and $\frac{5}{8}$ in. broad, and presented the very noteworthy phenomenon of bearing, like the leaves, chalk-scales on their under surface.

Conclusion.

It has been found convenient above to draw a hard and fast distinction between the two sets of secreting organs, viz. the Mettenian glands which are universally distributed over the vegetative organs, and the mucilage-glands which are confined to the axillary regions. As already hinted, however, glands displaying every stage of gradation from the one form to the other are met with in great abundance. Often, as in those of the axils of most species of *Acantholimon* and *Plumbago*, one has difficulty in deciding which name to apply. They offer no feature of distinction in the very earliest stages of development. At all times they respond to stains and reagents in an exactly similar manner.

The difference in their mucilage-secreting power is only one of degree. Young leaves of *Statice fruticans* for example, five or six inches long, sometimes have their whole upper surface bathed in mucilage, undoubtedly secreted by the Mettenian glands. The leaves of *Statice rosea* afford another instance of the same condition. *Aegialitis*, possessing modified in place of typical Mettenian glands, is probably in great part covered with the secretion. The contents of the Mettenian glands are evidently always of a mucilaginous character, even when functioning as chalk-secreting organs.

In the light of the above considerations there can be no doubt but that both sets of glands have the same origin. There is at the same time the greatest probability that the Mettenian glands are the primordial forms.

With respect to the stalked glands on the calyx of *Plumbago*, one can hardly hesitate in affirming that they are extremely specialised forms of Mettenian glands seen in the typical condition on the sepals of *Ceratostigma*, *Statice*, etc. On the other hand, their homology with mucilage-glands may be regarded as substantiated, in the light of the fact that mucilage-glands are found on the outer and inner sides of the sepals of *Aegialitis*, and that the sessile mucilage-secreting glands of both sides of the sepals of *Plumbago* are identical. The contention is strengthened by the appearance on the inner face of the calyx of *Vogelia* of sessile glands homologous with those of *Plumbago*. In regard to the elevation of the glands on pedicels it is well to recall that such happens occasionally in the axils of leaves of Statices, e.g. *S. sareptana*, and normally on the margins in *Plumbago micrantha*.

Previous investigators have referred to the correlation which subsists between the climatic conditions under which certain species grow and the amount of calcium carbonate secreted by them. Volkens experimented with leaves of *Limoniastrum monopetalum* cut from the plant. In the one case he removed the chalk-scales, and in the other left them over the glands. The result was that the former in an hour had lost by transpiration 26 per cent. of weight, and the latter 3 per cent.; and after three hours the one was quite withered, while the other remained fresh. From this he justly concludes that the purpose of the chalk-scales is to protect the plant from excessive transpiration, a necessary provision in its arid habitat. The plant in question affords an extreme and very intelligible case. From this example quite a series, involving all genera, could be constructed, showing gradual decrease in the number and size of the scales, until, as in almost all Armerias, no calcium carbonate appeared at all. This problem then suggests itself,—Were the Mettenian glands originally mucilage-

secreting organs, the chalk-secreting faculty being afterwards acquired? One is inclined to answer this in the affirmative, for the alternative, viz. that the chalk-secreting function was the original, does not seem tenable, seeing that it implies that the necessity for protection by chalk-scales existed in all or in the great majority of the members of the family.

With respect to the purpose subserved by the mucilage, extreme cases here also demonstrate clearly enough that protection is effected by it. In *Statice rosea*, as already remarked, it coats portions of the leaves in drought with a thin brittle film, and when the atmosphere is humid it swells up in the axils of this species, and of *S. fruticans*, and envelops the buds and tender bases of the leaves. Unquestionably, its hygroscopic power will be of service in attracting, storing and economising atmospheric moisture. But difficulties meet us when we try to explain its presence in the leaf-axils of plants (*Armeria*, *Statice*) which live in marshy stations with the bases of the leaves often in contact with the humid soil. Extended research with living plants in their native haunts is called for, before a full and comparative account of the physiology of the glands can be given.

The possession of Mettenian glands is most probably a universal feature in the cotyledons of the family. The absence of the mucilage-glands from the cotyledons of the *Plumbago* examined points to the likelihood that only certain genera possess them in that situation. One is apt to imagine that they are likely to occur there in genera possessing them conspicuously in the adult; in *Aegialitis*, for example, and, conversely, not in *Acantholimon*. Maury has been more fortunate than I hitherto in being able to get good seed of the latter. Although he does not mention any special glands in the cotyledons of this genus, they may nevertheless be there, seeing that he makes no note of them in *Armeria* and *Statice*, where they do occur distinctly. If they are present the question arises, Did Acantholimons formerly more closely resemble Armerias and herbaceous Statices in habit

and constitution, and bear abundant mucilage-glands, at which time the distinctive feature was transmitted to the seedling? Or might not the presence of the glands lead one to surmise that these three genera might have had a common ancestry, this character lingering distinctly in the seedling although almost entirely lost now in the adult *Acantholimon*? If they are not present, the problem becomes more complicated. Their invariable occurrence in the cotyledons of Armerias and Statices may safely be presumed, and they indicate very markedly the essential uniformity of structure and habit of the two genera. Their absence from the cotyledons of *Plumbago* opens up a wide field of speculation. It would be vain at present to attempt to elucidate the intricate and far-reaching problems in embryogeny which confront us in connection with the presence or absence of the cotyledonary mucilage-glands. A much fuller enquiry must first be made with other genera and species. The causal conditions which lead to the acquirement of the glands in the axils of the leaves lead also to their appearance in the cotyledons. The vicissitudes undergone by the parent and seedling are essentially the same. The occurrence of the glands in the cotyledons of *Armeria* and *Statice* certainly points to some occult and exceedingly important function which the mucilage performs in the economy of the species.

A considerable variety of plants having affinity with the Plumbagineae have been studied, with the object of ascertaining whether the latter alone possess the forms of glands above described. The glands of Frankeniaceae and Tamariscineae already described by Volkens[1] most nearly approach them, the latter especially bearing, in respect of both form and function, a marked resemblance to chalk-secreting Mettenian glands. The Frankeniaceae are recognised to be related, although remotely, to the Plumbagineae[2], and it is a

[1] Volkens, Flora d. Ægyp.-Arab. Wüste, 1887, Taf. v, Figs. 12, 13, and 8, 9.

[2] Le Maout and Decaisne, Traité général de botanique, Eng. ed. 1876, pp. 527, 253, 264.

remarkable coincidence that they affect maritime situations and are mucilaginous in character. The Tamariscineae have close affinity with the Frankeniaceae and 'prefer sea-shores, the margins of brackish lakes, the banks of rivers and torrents, in sandy or clayey soils.' The colleters on the ochreae of Polygoneae[1] and the capitate hairs of Plantagineae[2] are worthy of remark, both orders being associated with Plumbagineae. The mucilaginous condition of the former recalls the similar appearance of herbaceous Statices, and the leaves of many of the latter simulate in form the same organs in certain Armerias and Statices to a remarkable degree.

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[1] Hanstein, Ueber die Organe der Harz- und Schleimabsonderung in den Laubknospen, Bot. Zeit., 1868.

[2] Vesque, Caractères des Gamopétales, Ann. Sci. Nat., sér. 7, tome I, 1885, p. 349.

EXPLANATION OF FIGURES IN PLATES X, XI, XII, XIII.

Illustrating Dr. Wilson's paper on the Mucilage- and other Glands of the Plumbagineae.

PLATE X.

Fig. 1. A branch of *Statice rosea*, nat. size. *m*, mucilage bathing the bud; *m'*, semi-hardened mass of mucilage, secreted by the axillary glands.

Fig. 2. Hardened mucilage-cast of a portion of the leaf-surface of *S. rosea*. *ig*, intermediate gland, ·13 mm. in diameter.

Fig. 3. The apex of a branch of *Statice fruticans*, nat. size. *tr*, axillary trough.

Fig. 4. Epidermis of the apical portion of rachis of *Statice pruinosa*. i, ii, iii, iv, v, progressive stages of development of the rosette of cells surrounding the Mettenian glands[1]. The furthest developed (v) is ·5 mm. in diameter.

Fig. 5. Epidermis of rachis of *Statice chrysocomia*. The numerals signify progressive stages of modification. The whole elevated mass in iii. is ·26 mm. in diameter.

Fig. 6. Mettenian gland (chalk-secreting) on the leaf of *S. rosea*, having the lower edge bounded by a cushion of elevated cells ·4 mm. in breadth.

Fig. 7. A similar modification of cells on the upper side of the leaf of *Statice articulata*, breadth ·5 mm.

Fig. 8. The same in *Statice cordata*, ·35 mm. in diameter.

Fig. 9. An average-sized leaf of *Limoniastrum monopetalum*, nat. size.

Fig. 10. Chalk-scales, *ls*, on the leaf of *Statice macrorrhabdos*. Enlarged.

Fig. 11. Intermediate gland on the leaf of *Statice puberula*. *h*, tuberculated hair, 1·3 mm. in length.

PLATE XI.

Fig. 12. Emergence on the margin of the leaf of *Plumbago europaea*. *g*, Mettenian gland. Enlarged.

Fig. 12a. Apex of the same.

Figs. 13, 14. Stages of development of Mettenian glands on the margin of the leaf of *Plumbago micrantha*.

Fig. 15. A group of Mettenian and intermediate glands on a young leaf of *P. micrantha* (basal cells only figured).

Fig. 16. Modified gland, replacing Mettenian, in *Aegialitis annulata*. Outer circle, ·2 mm. in diameter; inner circle (mouth of gland), ·1 mm.

Fig. 17. Leaf of *Statice puberula*, nat. size.

[1] The walls of the glandular cells are almost invariably portrayed as somewhat swollen in preparation.

Fig. 18. Leaf of *Statice axillaris*, nat. size.

Fig. 19. Leaf of *Statice cylindrifolia*, nat. size.

Fig. 20. A group of mucilage-glands in the axil of the leaf of *S. macrorrhabdos*. *b*, basal cells; *c*, cap cells; *m*, mucilage.

Fig. 21. Vertical section of a mucilage-gland of *S. rosea*, ·35 mm. in diameter.

Fig. 22. Stalked mucilage-gland (axillary) found in *Statice sareptana*.

Fig. 23. Branch of *Armeria vulgaris* from an estuarine mud-flat. Nat. size. *cr*, surface-level of the soil.

Fig. 24. Tap-root and crown of a seedling of *Armeria chilensis*. Nat. size.

Fig. 25. A mucilage-gland of the same, swollen by imbibition of water in preparation.

Fig. 26. Upper portion of the epidermis of the inner side of the bract-sheath of *A. vulgaris* bearing mucilage (*c*), intermediate (*i g*), and Mettenian glands (*g*). *s*, stoma. is ·4 mm. in diameter.

Fig. 27. A mucilage-gland (axillary) of *Aegialitis annulata*, ·5 mm. in diameter.

PLATE XII.

Fig. 28. Mucilage-glands in the axil of a leaf of *Vogelia indica* var. *socotrana*, ·62 mm. in diameter.

Fig. 29. Upper portion of a sepal of *Vogelia pendula*. *gl*, glands on the inner face. Enlarged.

Fig. 30. A calycine gland of *V. pendula*, ·17 mm. in diameter.

Fig. 31. A mucilage-gland of *Acantholimon cabulicum*, ·17 mm. in diameter.

Fig. 32. A mucilage-gland in the axil of a young leaf of *Plumbago zeylanica*, ·28 mm. in length. *b*, basal cells. *c*, secreting cells.

Fig. 33. Intermediate gland in the axil of the leaf of *Plumbago europaea*, ·2 mm. in length. *ac*, *Nebenzellen*.

Fig. 34. Portion of the margin of the leaf of *Plumbago micrantha*, bearing multicellular glands.

Fig. 35. A marginal gland of the same, fully developed.

Fig. 36. Upper part of the calyx of *Plumbago rosea* bearing stalked glands. Enlarged.

Fig. 37. Conical intrusion of the stalk of the calycine gland of *Plumbago scandens*.

Figs. 38, 39. Optical sections of the head and the stalk of a nearly sessile external calycine gland of *Plumbago rosea*.

Figs. 40, 41. Head (·13 mm. in diameter) and stalk of internal calycine gland of *Plumbago zeylanica*.

Fig. 42. Trough formed by the fused bases of the cotyledons of *Armeria vulgaris*. *mg*, mucilage-gland.

Fig. 43. A mucilage-gland from the cotyledonary trough of *Armeria vulgaris*.

Figs. 44, 45. Basal cells of young mucilage-glands in the same position.

Fig. 46. A developing mucilage-gland, ·1 mm. in diameter, in the same position, showing nuclei (*n*) and nucleoli.

Fig. 47. Seedling *Armeria vulgaris*, not yet above ground, nat. size.

Fig. 48. Cap-cells of a mucilage-gland from the above seedling arranged with noteworthy regularity.

Fig. 49. A germinating seedling of the same species, nat. size.

Fig. 50. Developing mucilage-glands in this seedling (Fig. 49). The smaller gland ·05 mm., the larger ·11 mm. in diameter.

Fig. 51. Abnormal seedling of the same species. Nat. size.

Fig. 52. Cap-cells of a young mucilage-gland ·2 mm. in diameter, after treatment with solution of caustic potash.

Fig. 53. Two cap-cells of the same liberated by rupturing the gland under pressure.

Figs. 54, 55. Germinating seedling of *Armeria plantaginea*, invested in (54) and free from (55) the calyx. Nat. size.

Figs. 56, 57. Germinating seedling of *Armeria latifolia*, nat. size.

Fig. 58. A Mettenian gland, *g*, in the above seedling of *Armeria latifolia*, at a very early stage of development.

Fig. 59. A later stage of the same as in Fig. 58.

Fig. 60. An advanced seedling of the same species, nat. size. *m s*, swelling indicating the position of the gland-bearing trough; *lf*, leaf.

Fig. 60 a. Young seedling *Plumbago zeylanica*, nat. size.

PLATE XIII.

Fig. 61. Cells of the base (·12 mm. in diameter) of a mucilage-gland from seedling *Armeria vulgaris* (Fig. 51). *mr*, mucilaginous boundary of the cell-wall after treatment with solution of caustic potash.

Fig. 62. Cells of the base (·08 mm.) of a mucilage-gland in a very young seedling, exhibiting the same feature as above.

Fig. 63. Upper (secreting) surface of a mucilage-gland (·16 mm.) in a young seedling of *Statice tatarica*, after immersion in solution of caustic potash.

Fig. 64. Basal cells of the same gland.

Fig. 65. Mucilage-glands (*m g*) in the axil of the cotyledon of *Statice Thouini*. *k*, margin of trough formed by the fused bases of the cotyledons; *lf*, leaf.

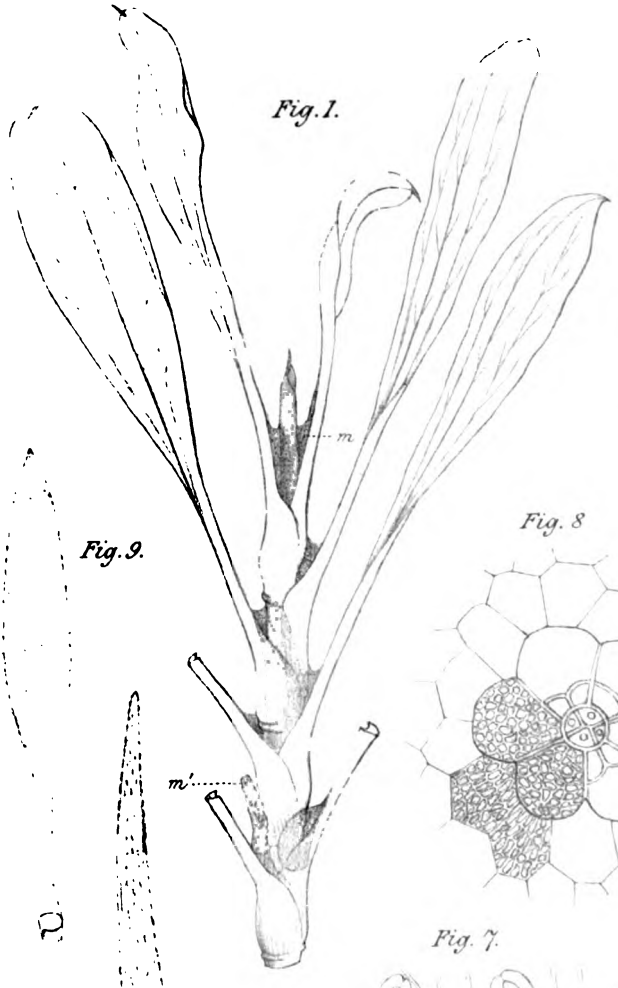
Fig. 66. A portion of the same region more highly magnified.

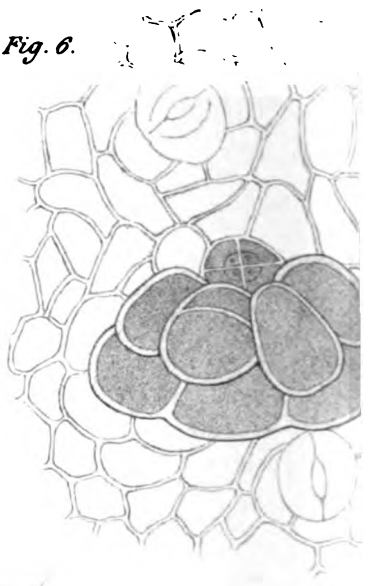
Fig. 67. Transverse section of the cup. *m g*, mucilage-gland; *lf*, young leaf.

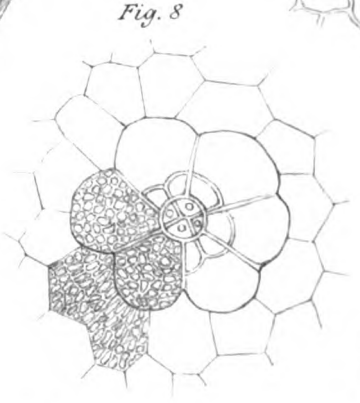
Fig. 68. Sessile gland on the inner face of the calyx of *Plumbago scandens*, ·15 mm. in diameter. *b*, pyramidal basal cells.

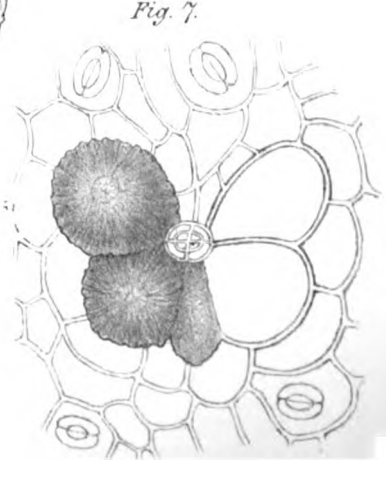
Fig. 69. A mucilage-gland at the base of the cotyledon of *Statice duriuscula* (long axis ·18 mm.), with inner concentric division and general partition into four.

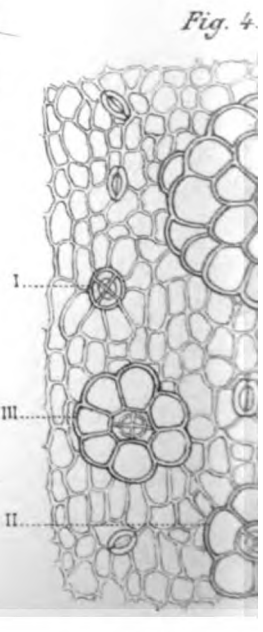
Fig. 70. Sessile gland on the inner face of the calyx of *Plumbago rosea*, ·12 mm. in diameter. *b*, base.











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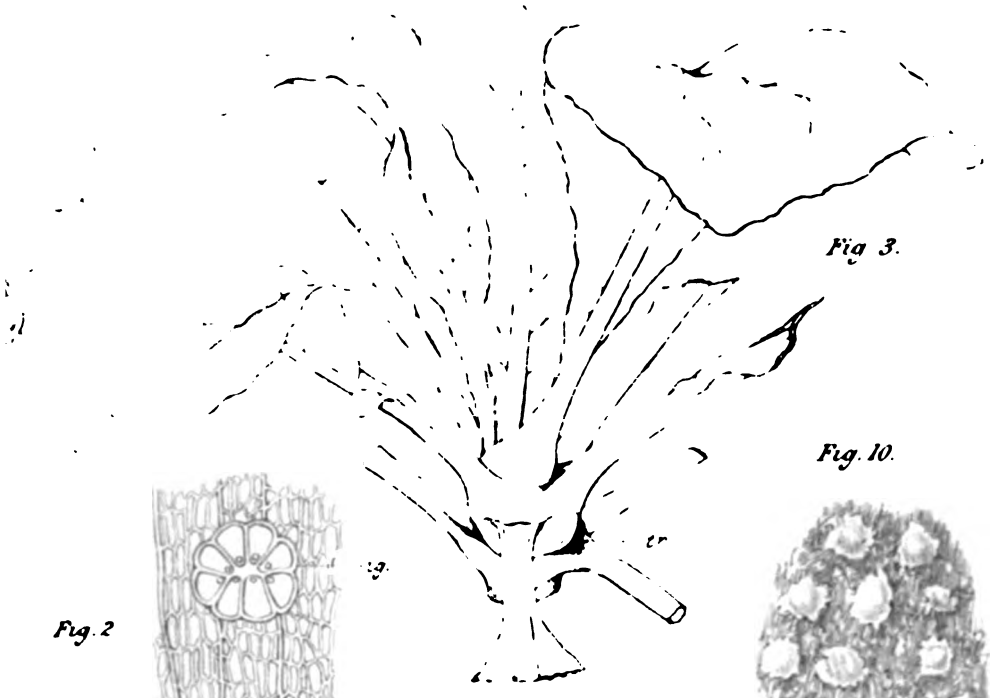

Fig. 3.

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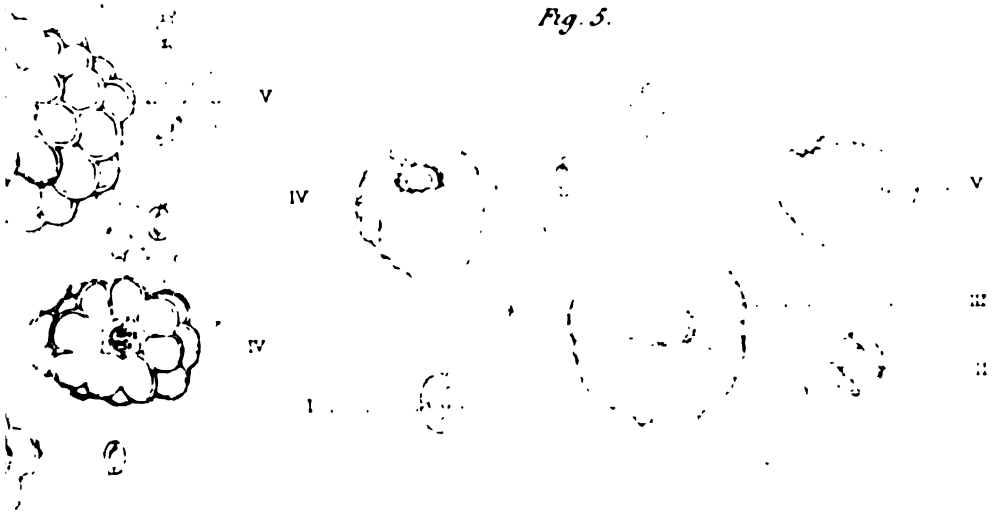

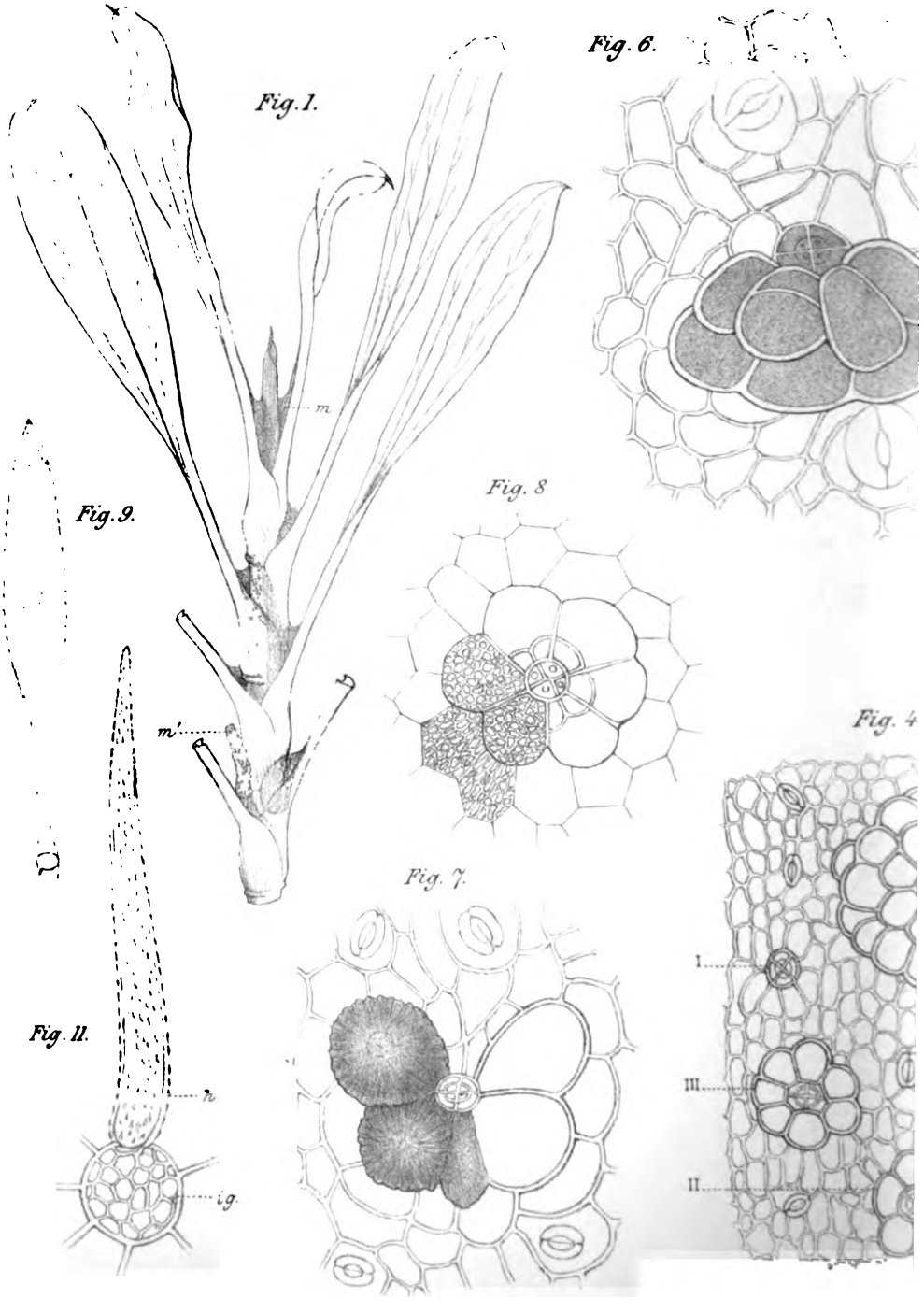

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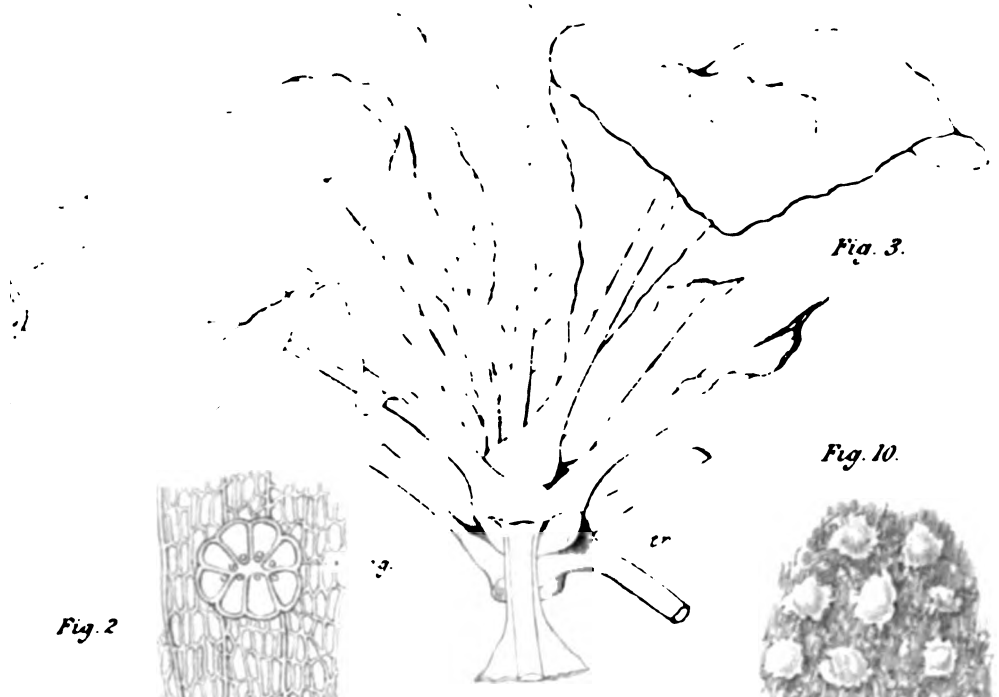
Fig. 3.
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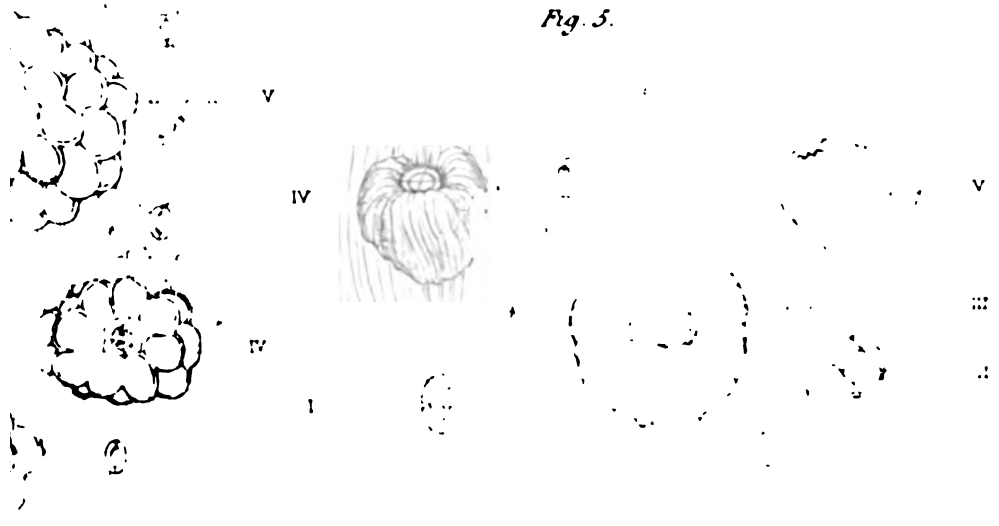
Fig. 5.
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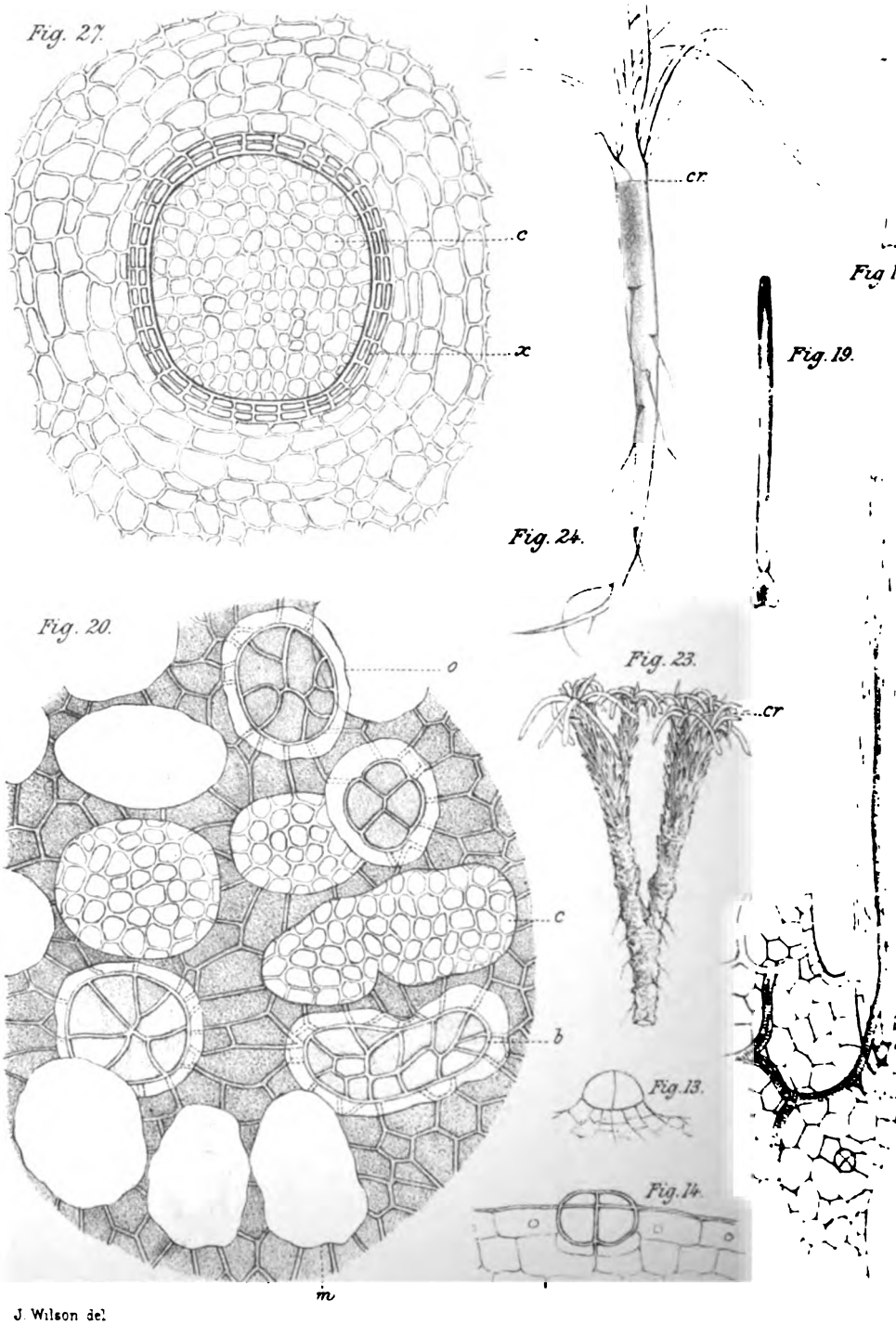

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WILSON.— ON THE GLANDS OF PLUMBAGINEAE.

Fig 15

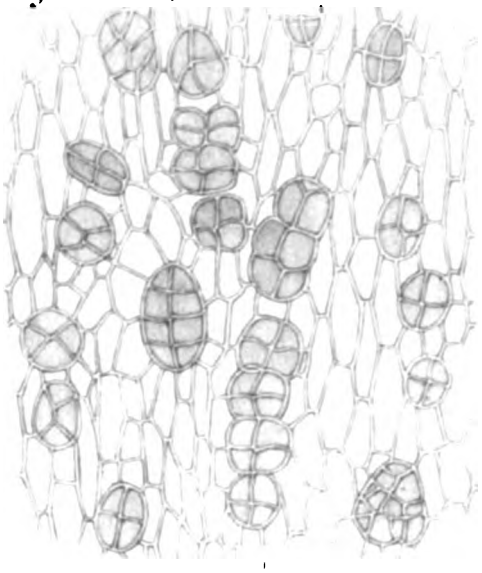
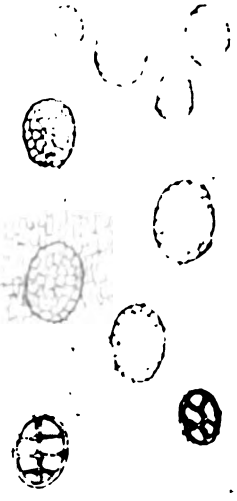


Fig 17

Fig 12a

Fig 26



b

Fig. 16

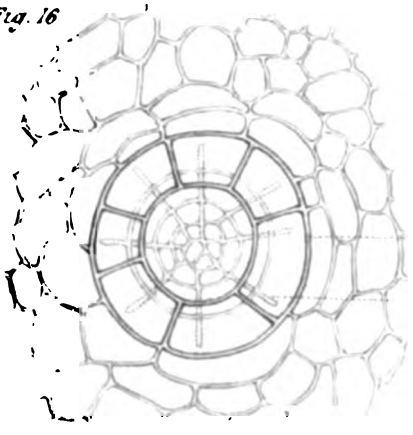


Fig 25

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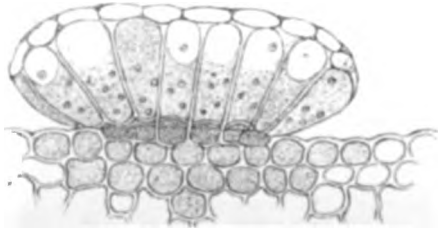
b

Fig 22

g

Fig 12

Fig 21



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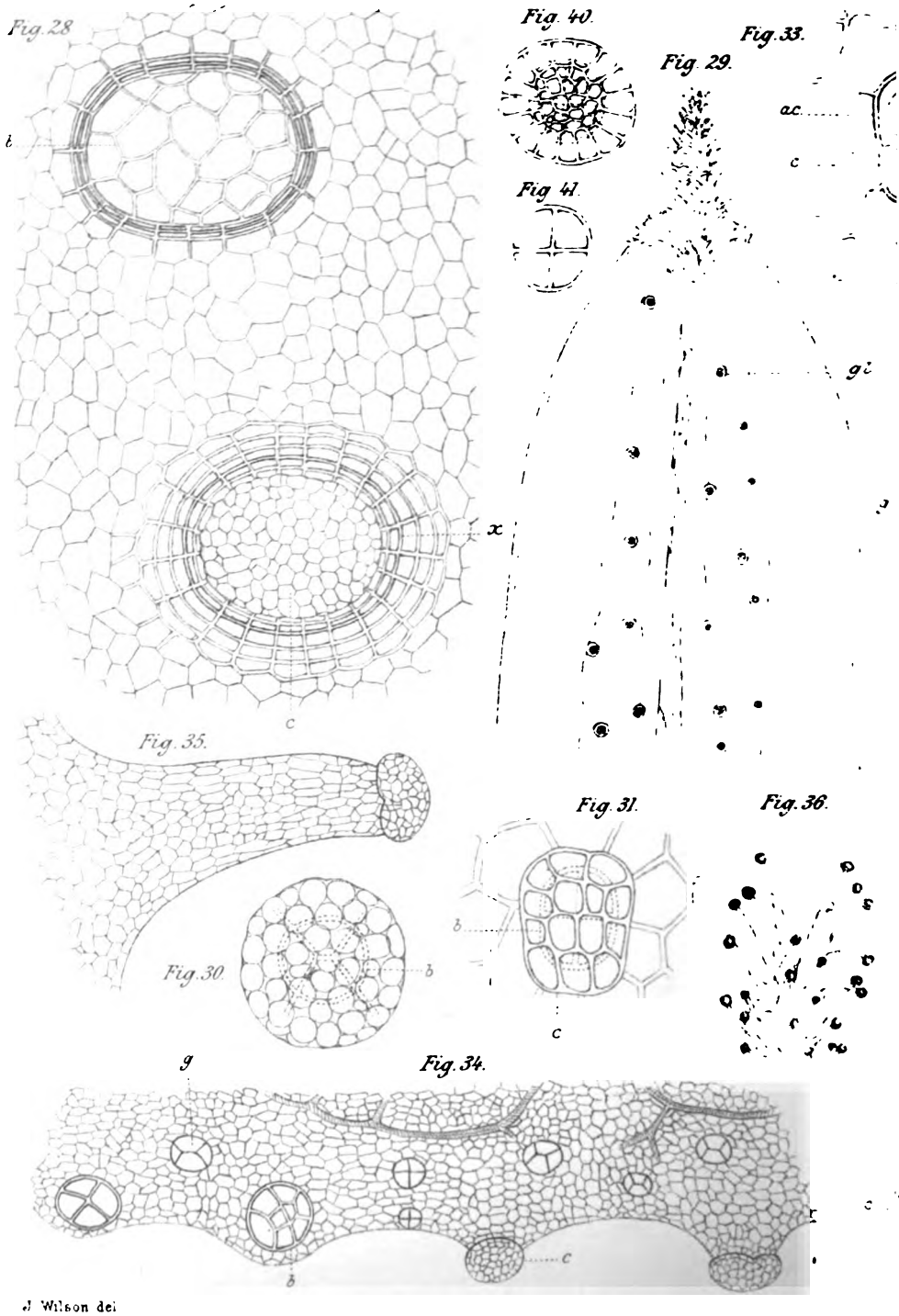
Fig. 28
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Fig. 34.
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c

J. Wilson del.

Fig 32

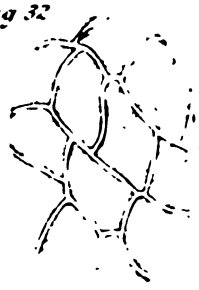

Fig 37

Fig 38

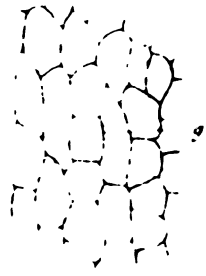

Fig 39

Fig 60

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Fig 51

Fig 42

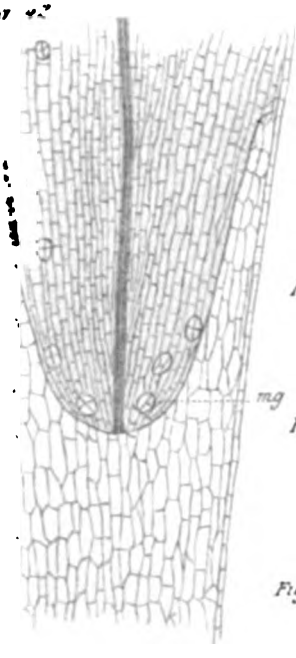

Fig 60a

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Fig 49

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Fig 54 Fig 55

Fig 43

Fig 44 Fig 45

Fig 46

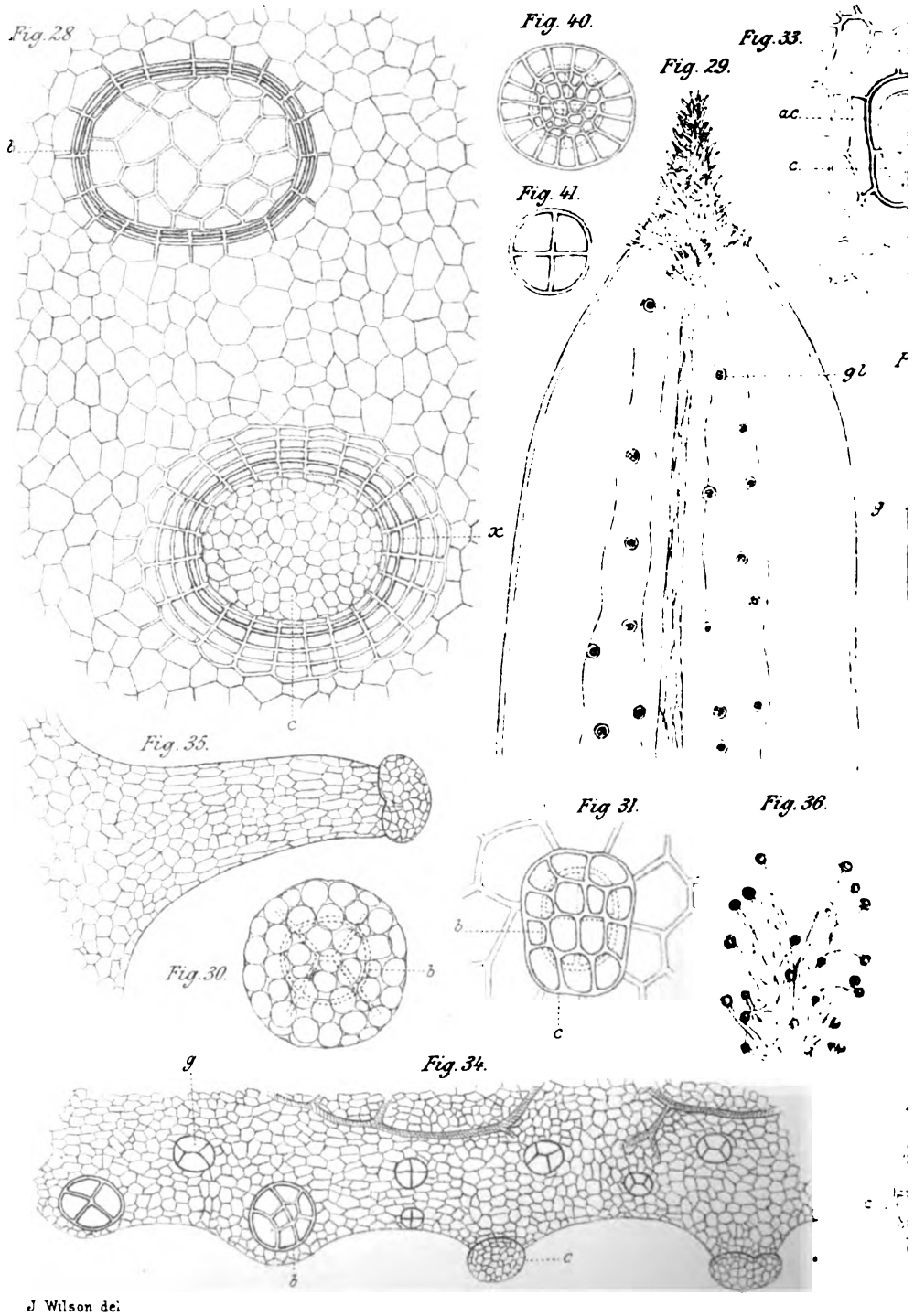
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Fig. 32

Fig. 37

Fig. 38

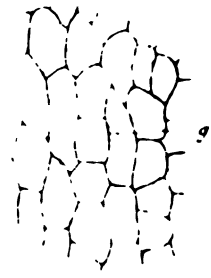

Fig. 39

Fig. 50.

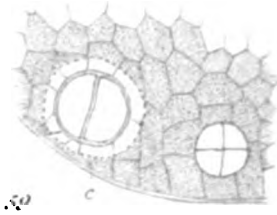

Fig. 60

Fig. 51

Fig. 42

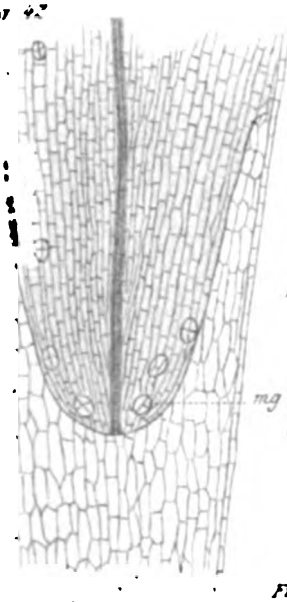

Fig. 60a

Fig. 49

Fig. 56 Fig. 57

Fig. 48 Fig. 53

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Fig. 46

Fig. 54 Fig. 55

Fig. 44 Fig. 45

Fig. 52

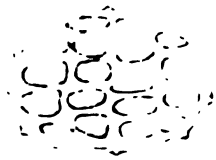

Fig 63

Fig 66

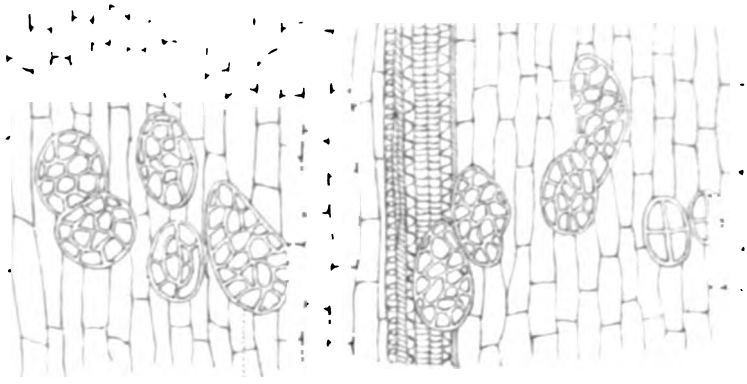

Fig 64

Fig 62

Fig 65

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Fig 67.

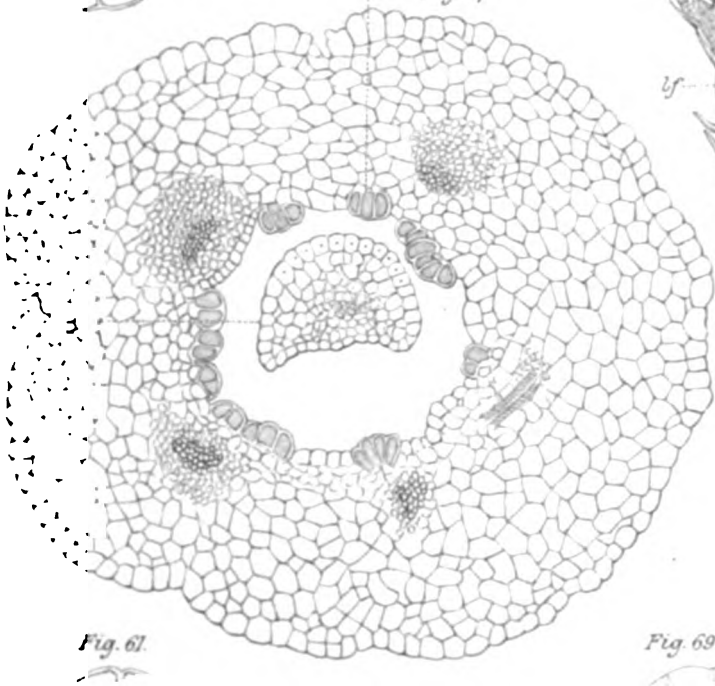

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Fig 61.

Fig 69.

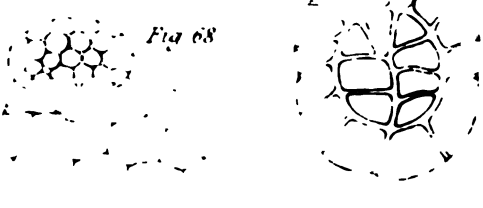

Fig 68

Fig 70

Note on the Fertilisation of Musa, Strelitzia reginae, and Ravenala madagascariensis.

BY

G. F. SCOTT-ELLIOT, M.A. Cantab., B.Sc. Edin.

With Plate XIV.

MUSA.

THE flowers are some 2½ inches long and arranged in whorls along the drooping peduncles. The three sepals and two inferior petals are united into a tubular sheath enclosing the stamens and style. There is a slight exudation of gum at the tip of this sheath which renders the union of the parts very close.

The odd petal eventually emerges between the superior sepals and swells out into a sort of concave dome guarding the honey (see Fig. 21).

Partly by this emergence, and partly by intercalary growth of the two lower petals, the sheath enclosing the stamens and style is forced open. There does not appear to be an explosion of pollen (as in *Ravenala*), but on emergence the sheath and stamens are strongly bent downwards and the style curved upwards. In this position the flower is ready for fertilisation, and the position of the stigma above the stamens will lead to cross-fertilisation although self-fertilisation is not excluded.

The following additional details may be worth noticing. There is a marked S-shaped curve in the middle line of the superior petal. As may be well seen from young flowers, this is due to the petal (while enclosed in the sheath) being unable

to develope longitudinally while it can expand laterally. The upper stamen is not developed, being probably in the way, and there is sometimes a reduction in length of the next superior stamens.

The usual fertilisers of the banana, at least in Natal, are sunbirds, but insects appear often to assist[1] (notably bees), while in Mauritius insects must be the only fertilisers.

RAVENALA MADAGASCARIENSIS.

This flower shows a great advance on *Musa* in specialisation. The flowers are very large, but each peduncle has only seven to nine (in some cases twelve) bracts which correspond to the almost indefinite number of whorls in the banana.

The bracts, each of which contains a large number of flowers closely packed together, are large (16 inches long) and very rigid, their upper edges being in contact above the flowers, which emerge between their superior edges one by one as they ripen. The three sepals are free in *Ravenala* before the flower rises between the edges of the bracts[2], but a sheath quite similar to that of *Musa* is formed by the close union of the two lower petals only. This encloses the stamens and is hard and sclerenchymatous in structure.

The odd petal is much shorter than the other two, but not very different in shape.

The six stamens enclosed in this sheath are unable to elongate, and hence become very strained. The style has six longitudinal grooves on which the anthers shed most of their pollen (though some is retained in the anthers). Part of the extremity of the style projects through the end of the petal sheath.

When the flower rises between the rigid edges of the bract, it is in a very strained condition, and the two upper edges of the united sepals gradually separate. In this state, a touch on the end of the sheath sets the two petals free, the stamens and style at once spring into the position shown in Fig. 24,

[1] Cf. Müller, Verh. d. natur. Ver. d. preuss. Rhein. ü. West. i. 1878, and Hildebrand, Bot. Zeit., xxviii, p. 273, 1870.

[2] In the bud they are closely united round the petals, just as in *Musa*.

while a cloud of pollen is scattered. The two stigmatic lips subsequently open.

It is interesting to note that the two upper edges of the inferior petals overlap, as in *Strelitzia*, though not to the same extent.

The flowers are often visited by sunbirds: *Nectarinia souimanga* was the commonest near Fort Dauphin. The correct position of the bird is to sit on the next highest bract and then bend forwards and downwards to suck the sugary liquid by introducing its beak below the odd petal. In doing this it will explode a virgin flower, dusting its breast with pollen, while in older flowers it will touch the stigmatic surface and so effect cross-fertilisation. Sometimes it hops into the middle of the flower, however, or tries to reach the honey from the same bract by bending round the petals. Beetles and Hymenoptera often visit the flowers to suck the sugary liquid which exudes over the edges of the bract. They will only produce fertilisation by accident, however, while the narrow curved beak of the bird is excellently adapted to pass between the edges of the rigid bracts and suck the honey.

STRELITZIA REGINAE. Ait.[1]

The flowers, though similar to those of *Ravenala*, are still more specialised. The sepals are bright scarlet, while the petals are a deep purplish blue[2], instead of the pure white of *Ravenala*. The spathe is quite similar to that in *Ravenala*, but there is only one to each peduncle out of which the flowers emerge one by one.

The petaline sheath particularly is still more specialised. The shape of the united pair being somewhat like that of an arrowhead with the flanges slightly turned up (see Figs. 26, 27).

[1] The structure of this flower is roughly described by Hildebrand (Botan. Zeit. 1869, p. 508), but several important points are not alluded to; cf. also Delpino (Atti della Soc. Ital. d. Sci. Nat. in Milano, vol. xi and xii). Darwin mentions the fact of its being fertilised by birds (Effects of Cross- and Self-fertilisation. London, 1876).

[2] The shades both of red and blue being exactly the same as those on the breast of the beautiful *Cinnyris* (*Nectarinia Afra*) its visitor.

The breadth across the broadest part of the arrowhead is about ten lines. The odd petal is small, three quarters of an inch long and dome-shaped, completely covering the entrance to the honey.

The anthers occupy the whole length of the broad part of the arrowhead (some 2½ inches), while the style projects almost an inch in front of the petals. If the flanges are pressed down, the tubular cavity opens and exposes the six anthers.

The superior edges of the united petals have a peculiar structure. In the broadened portion they are only about a line broad (though overlapping), but where the narrow part of the arrow-head begins they suddenly expand to about half an inch, at the same time overlapping in the peculiarly perfect way shown in Fig. 30. Insects must be completely prevented therefore from entering the flower from above.

Professor Maccowan informs me that the bird walks along the flanges (probably developed for this purpose) and in bending down beneath the dome-shaped odd petal probably causes the petaline sheath to open so as to dust its breast with pollen. The stigma being in front of the petals will of course be touched first.

I have often seen the honey-bee and Diptera (*Lucilia argyrocephala* and others) sucking the gummy juice which exudes from the spathe, but it is not I think possible for insects to produce fertilisation as Hildebrand[1] supposes may happen, unless very exceptionally indeed. Unfortunately I could not visit its proper habitat, and, in spite of several days watching, I never saw any birds near it in the Cape Town Gardens.

[1] Hildebrand, loc. cit.

EXPLANATION OF FIGURES IN PLATE XIV.

Illustrating Mr. G. F. Scott-Elliot's paper on the Fertilisation of *Musa*, *Strelitzia reginae*, and *Ravenala madagascariensis*.

Figs. 21–23. *Musa species.* Nat. size.

Fig. 21. Longitudinal mesial section of flower.

Fig. 22. Young flower not open, seen from above.

Fig. 23. Transverse section to show arrangement of petals and sepals.

s, sepals; *p*, petals; *p o*, odd petal; *st*, stamens; *sti*, style; *h*, horny tip to sepals.

Figs. 24, 25. *Ravenala madagascariensis.*

Fig. 24. Open flower. One quarter natural size.

Fig. 25. Young flower not open.

Lettering as above, except *fl*, young flower.

Figs. 26-30. *Strelitzia reginae.*

Fig. 26. Flower. One half natural size.

Fig. 27. View of arrow-shaped petal sheath from above.

Fig. 28. Style, thickened extremity.

Fig. 29. Transverse section of petal sheath, broad portion.

Fig. 30. Same in narrow tubular portion near the base. Showing manner in which the upper ends of united petals are folded within each other.

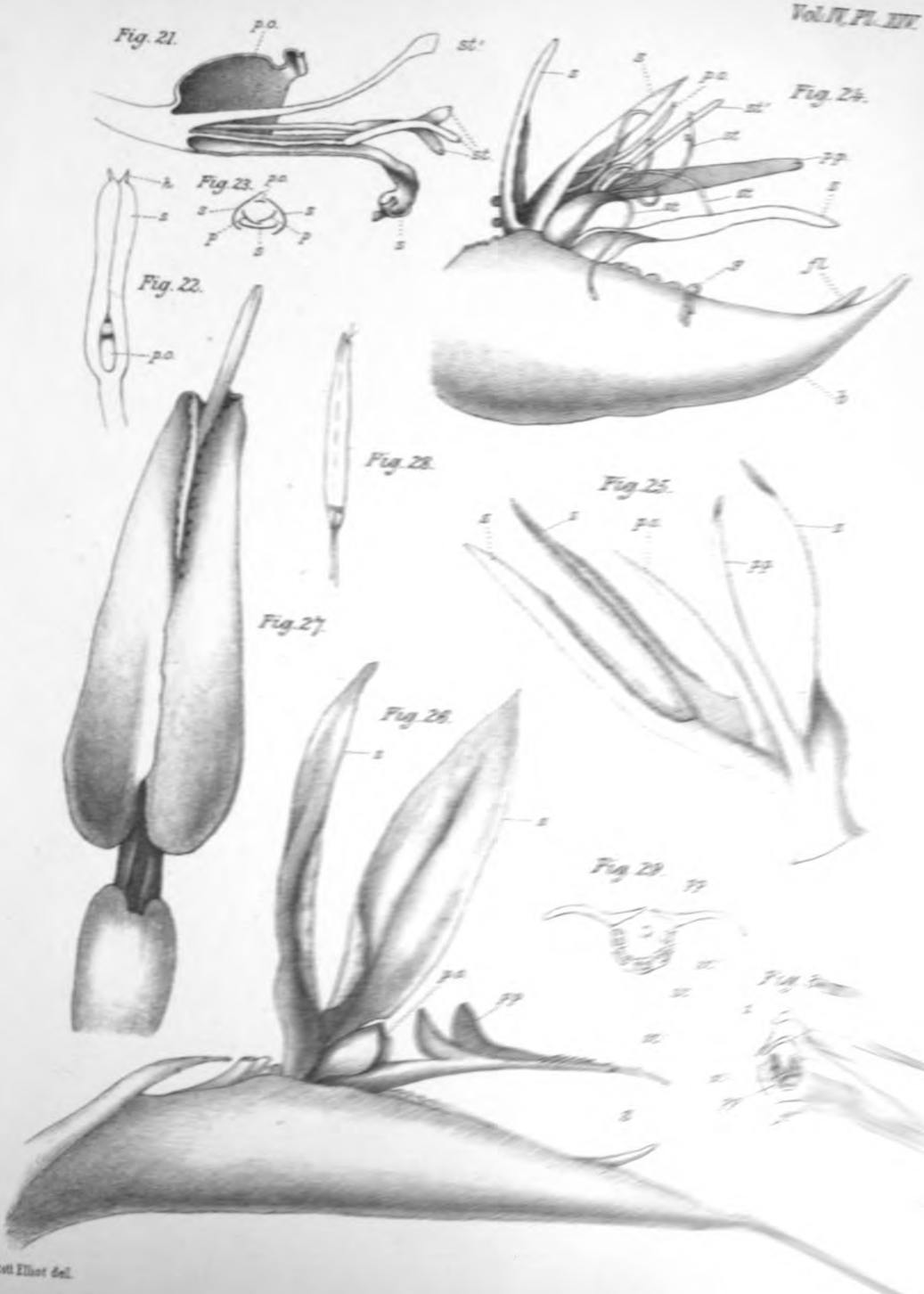
Fig. 21.
p.o.
st'
st.
s
Fig. 23.
p.o.
s
p
Fig. 22.
p.o.
Fig. 24.
s
p.o.
st'
st
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Fig. 28.
Fig. 25.
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Fig. 27.
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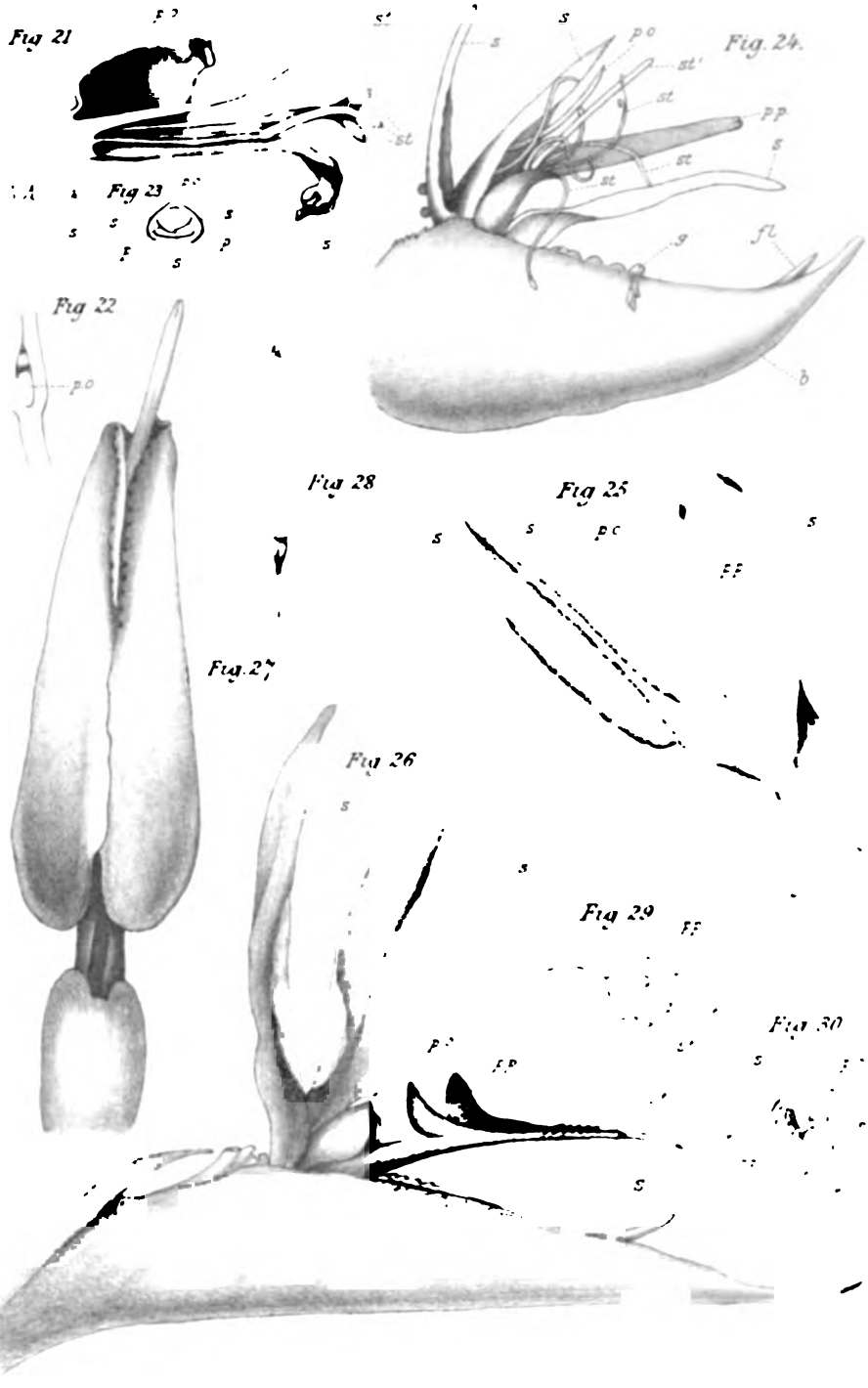
Fig. 3
Scott Elliot del.



Scott Elliot del

SCOTT ELLIOT — ON FERTILISATION IN MUSA, STRELITZIA & RAVENALA

Ornithophilous Flowers in South Africa.

BY

G. F. SCOTT-ELLIOT, M.A. Cantab., B.Sc. Edin.

With Plate XV.

THE Cinnyridae play a very important part in the fertilisation of some of the Cape flowers. There has been very little published on this point[1], and therefore the following observations on flowers belonging to some thirteen natural orders may be of interest, especially as probably more than a hundred species are largely fertilised by these birds. It is noticeable that the orders are perhaps as different as they possibly could be.

MELIANTHUS MAJOR, L. (Figs. 1–3).

The flowers are exceedingly conspicuous. The peduncle is four or five feet high, and thickly covered for the last eighteen inches by the dark reddish-purple flowers.

The sepals are petaloid and very dissimilar; the superior pair (about an inch long), being slightly curled forwards, protect the essential organs from rain[2]; the lateral sepals are somewhat shorter, and prevent access to the flower from the side; the lowest sepal[3] is hollowed out into a short blunt

[1] Dr. Trimen. Lecture delivered before the Cape of Good Hope Society.

[2] They also overlap behind one another.

[3] The flowers are reversed by the twisting of the pedicel.

[Annals of Botany, Vol. IV. No. XIV. May 1890.]

spur, which comes so far upwards in front that it meets the extremities of the petals. These latter are bent forwards at right angles to the flower axis and converge to a point just covered by the anterior border of the lowest sepal. They are united laterally (the lower pair in front also), and hence aid in preventing insect visits from the side [1].

The honey-secreting disc does not surround the essential organs, but is only developed between the bases of the lower pair of stamens. It is very large and cup-shaped, having almost the same shape as the sepaline spur in which it lies, and to which it is united behind and for about a line in front. It secretes an abundance of rich black honey, which sometimes almost fills the cup. The only entrance to this honey is from above, through the horizontal arch formed by the petals.

The flower is protandrous, and shows three distinct stages.

In the bud the four stamens surround the style, with the anthers introrse; but just before dehiscence the superior pair of stamens elongate till their anthers are just below the superior sepals, at the same time twisting so that the dehiscing anthers have their faces turned downwards.

In the second stage the same process occurs with the lower pair of stamens, but the elongation is not so great (see Fig. 2).

In the third stage the anthers are carried outside the flower by a continuation of the twisting process (through another 90°, see Fig. 3), while the style elongates and bends forwards; the minute stigmatic lips also enclose.

I saw the birds (*Nectarinia chalybea*) at work at Duiker Vlei, near Cape Town. They seize the peduncle below the lowest flowers and hop upwards. This is almost invariably their habit with all flowers, and the protandry in this case leads to their cross-fertilising different plants. They let me approach within ten yards, and I could see them, while clinging to the peduncle, take the range of the upright flowers and dip their beaks into the spurs, thus covering the head feathers

[1] The petals have small reflexed extremities. These are covered with hairs, and would perplex any small insects crawling into the flowers.

with pollen in younger flowers or touching the stigmatic lips in older ones.

MELIANTHUS COMOSUS, Vahl.

This flower is not so much specialised as the preceding species. The petals are quite free and more upright, while the spur of the lower sepal is not so marked, and the honey-secreting disc is much smaller. The four anthers also dehisce at the same time [1].

This plant, which grows in the Karoo, is visited by another *Cinnyris* (*Nectarinia famosa*).

MELIANTHUS DREGEANUS, Vahl.

Visited by *Zosterops virens* near Seymour, Stockenstrom (*fide* Mr. W. C. Scully).

LEGUMINOSAE.

SCHOTIA SPECIOSA, Jacq.

The flowers are protogynous; the pistil is usually flaccid when the anthers have all emerged from the perianth.

The bright scarlet flowers are very conspicuous. Mr. W. C. Scully watched the birds (probably *C. chalybea*) at work on this plant.

ERYTHRINA CAFFRA, D. C. (Figs. 4–5).

The vexillum in this flower is very large and a brilliant scarlet, while the alae and carina are small and have no lever action whatever. The alae protect the honey from rain and insects as they overlap above the carina. The latter forms a sort of cup (see Fig. 5) in which the honey is held [2].

In the bud the stamens and style are enclosed in the vexillum: as the flowers ripen a sudden bend takes place in the staminal column, so that the stamens and style become nearly

[1] It appears to me probable that *Aitonia capensis*, or some similar form, may have been the ancestor of which *Melianthus comosus*, and then *M. major*, are the specialised descendants.

[2] The lower edges of the carina are united to keep in the honey.

parallel to the peduncle. The stamens diverge considerably and curve upwards in this condition. Hence in this state the end of the leafless peduncle is surrounded by a sort of brush of stamens.

The bird, as it hops along the peduncle and plunges its beak into the carina beneath the alae, has its breast well dusted with pollen; but it cannot effect self-fertilisation, as (see Fig. 4) the terminal portion of the style is abruptly bent towards the vexillum.

Subsequently both the stamens and styles, losing their upward curvature, bend still more downwards towards the peduncle until the style is so straightened that the stigma will touch the bird's breast when it approaches along the peduncle.

All the Nectariniae (and *fide* Mr. Scully *Zosterops virens*) are excessively fond of this flower, and apparently it wholly depends on them for pollination. Mr. E. S. Galpin tells me that 'the bird puts its beak in the opening on top of the staminal column, and runs it along the latter, thus raising the stamens.' Unfortunately I have not been able to test this interesting observation.

ERYTHRINA INDICA, L.

I was able to study the arrangement in this species in Mauritius. Fundamentally the structure is the same. A peculiarity, however, is the peculiar thickening of the upper borders of the carina, which renders entrance still more difficult. The nectary consists of ten small prominences enclosed by the staminal column. Though the stigma is bent over in the same way, I found, in the flowers I examined, that it lay below the level of the anthers. Not being in its natural habitat, I could not study its fertilisation, but in Mauritius it is certainly ornithophilous.[1]

SUTHERLANDIA FRUTESCENS, R. Br. (Figs. 6–8).

This flower shows the same excessive length of vexillum (15–16 lines) and reduction of alae (5–6 lines) so noticeable in *Erythrina*. In the bud, the flower has the characteristic ap-

[1] In a species of *Erythrina* described by Belt, 'Naturalist in Nicaragua,' p. 130, the flower axis seems perfectly straight, though the flowers are ornithophilous. Cf. also *E. velutina* and *E. cristagalli*. Hildebrand, Bot. Zeit. xxviii. p. 621.

pearances of a brush piston flower, like that of some vetches for instance. The vexillum covers the sides of the flower, overlapping laterally in front of the carina. There is a distinct pouch at the tip of the carinae enclosing the anthers which are packed in two whorls, with the usual difference in length of filament and size of anther in each whorl. The pollen is shed on a brush of hairs covering the inner face of the style[1].

When the vexillum opens, the whole mechanism of the flower becomes looser; the carina elongates and its pouch becomes obliterated, and the style grows with the carina, still bearing the pollen on its hairs.

On depression the style simply emerges. The alae take no part in depressing the carina, though possibly their auricles, which pass backwards under the claw of the vexillum, make the motion more steady and regular[2].

The flowers are much visited by *Cinnyris Nectarinia famosa* at Brakfontyn, near Beaufort West, in the Karoo (Miss Jackson).

ERICACEAE.

ERICA PLUKENETII, L.

The pendulous flowers form dense clusters at the ends of the branches. The corolla is ten lines long, narrowing to the throat. The anthers hang completely out of the corolla, extending to fully half an inch from the entrance (so that the distance from their extremities to the base of the flower is sixteen lines, which is exactly the length of beak of *Nectarinia chalybea*).

The stigma is about a line below the anthers, and so comes first in contact with the birds' heads. Honey is secreted by nectaries at the base of the flower.

This is abundantly visited by *N. chalybea* on the hills near

[1] Stigma protected from its own pollen by a small stiff ring of hairs.

[2] This flower seems to me very probably a modification of some such type as *Lessertia pulchra*, which is practically in the same condition as *Sutherlandia* before unfolding of the vexillum.

Cape Town. The bird always seizes the branch below the flowers, and exhausts one branch before going to another. It is an important article of diet to the birds, as it blooms practically all the year.

Probably the whole *Gigandra* section of *Erica* is ornithophilous except *E. penicillata*.

ERICA PURPUREA, Andr.

The flowers are purplish red, and are arranged almost horizontally. The corolla tube is much curved upwards, and about an inch long; it is also very viscid externally, thus keeping off insects. The style projects 2–3 lines from the throat of the corolla, while the laterally placed stamens are included in its tube.

The nectary consists of small projections from the base of the ovary, placed between the stamens.

I have often seen the flowers visited by *Nectarinia chalybea* at Wynberg Butts and Muizenberg. Owing to the upward curvature the bird has to seize the branch above the flowers and suck them head downwards. This is an advantage for the flower, as self-fertilisation is quite impossible, while in *E. Plukenetii* it must occasionally happen.

Probably the whole *Pleurocallis* section is ornithophilous. All the large flowered Evanthes are almost certainly so.

The section *Bactridium* is particularly adapted to bird-fertilisation; the rare *E. fascicularis* (Fig. 9), for instance, which grows on the summits of barren rocky hills near Houwhoek. The stems are three or four feet high without branches, and crowned by a thick whorl of scarlet flowers about sixteen lines long. I saw many birds near them, but had no time to watch them at work.

TECOMA CAPENSIS, Lind.

The stigma stands in front of the stamens with the lips horizontal, so that self-fertilisation is impossible.

I have seen this visited by *Nectarinia afra* in the Fish River Bush. It is also visited by *Zosterops virens* (*fide* W. C. Scully) and *C. amethystina*. Near East London I found numerous bees visiting the flowers. Mr. M. S. Evans has already pointed this out as an ornithophilous flower (*Nature*, vol. xviii. p. 543).

LYCIUM TUBULOSUM, Nees.

This plant is a tall shrub or small tree, with drooping white flowers. The corolla is ten lines long and considerably curved. The stigma is always in front of the stamens, so that cross-fertilisation is ensured. Honey is secreted by the base of the ovary.

I found it was abundantly visited by *Nectarinia chalybea* on the banks of the Little Fish River, near Somerset East. It is also much visited by *Apis mellifica* and other Hymenoptera, who crawl bodily into the flower. Various Coleoptera also visit the flowers.

LOBOSTEMON MONTANUM, Buek.

This plant is a shrub some four or five feet high. The leaves are crowded at the ends of the branches, and these latter being very close together, the bush forms a sort of domed cushion closely covered by pale purple flowers.

The flowers are distinctly irregular: the posterior lobes of the corolla are shorter than the anterior and the stamens of unequal length[1].

Honey is secreted very abundantly by a fleshy ring round the ovary, sometimes filling the corolla-tube to a depth of two or three lines. Insects are kept out largely by a ring of hairs springing from the base of the filaments (and corolla) which surrounds the style. The whole plant is excessively hairy, and the corolla externally viscid.

Though this flower is not specially adapted to birds, I have often seen it visited by *Nectarinia chalybea* sucking honey, and also by other birds (? *Promerops caper*) near Muizenberg. Insect visitors moreover are very rare.

The nearly allied *Lobostemon fruticosum*, Buek., is always covered by insects. The following I have gathered myself. Coleoptera: *Anisonyx ursus* always very ab., *Anisonyx longipes* ab., *Dichilus dentipes*, *D. simplicipes*, *Peritrichia capicola*, and others which I cannot name. Hymenoptera: *Ceratina subqua-*

[1] The shorter stamens twelve lines long, and the others thirteen or fourteen lines.

drata, Xylocopa caffra, Apis mellifica, Tetratonia longicornia. Lepidoptera: several species and numerous Diptera.

LABIATAE.

LEONOTIS OVATA, Spreng.

The flowers are arranged in two or more dense whorls separated by rather long internodes. The calyx tube is long and excessively rigid: the most remarkable peculiarity in the corolla is the almost rudimentary condition of the lower lip: the upper lip, which is of the usual Labiate type, forms a sort of roof protecting the stamens from rain.

The whole outer surface of the corolla is covered with long foxy-red hairs: these probably keep off unnecessary insects (in conjunction with the usual ring of hairs within the corolla just above the ovary).

Cross-fertilisation is ensured by the position of the stigma always above and in front of the stamens. Both style and stamens are covered by the upper lip of the corolla. Honey is very abundantly secreted by a very large nectary of the ordinary Labiate type. The distance from the stigma to the nectary is about sixteen lines, which is exactly that of the beak of *Nectarinia chalybea.* The flower is also curved with the same curvature as that of the bird's beak.

I found *Nectarinia chalybea* sucking the flowers on the Kagaberg, Bedford. The bird grasps the bare stalk below the whorl, then rapidly sucks all the flowers of the whorl, and hops up to the next internode, or more usually flies to another plant. Also visited by *Cinnyris Kirkii.*

The flowers are also visited by numerous bees, *Apis mellifica* and others, but these, unless when gathering pollen, cannot produce fertilisation[1].

SALVIA AUREA, L. (Figs. 19, 20.)

The plant is a shrub three to six feet high, and bears a pro-

[1] The withered lower lip prevents their obtaining a convenient entrance. I saw one bee repeatedly miss the opening and then fly away in disgust. The rigidity of the calyx (the distinctive character of the genus), colour and inflorescence, are all ornithophilous adaptations.

fusion of reddish yellow flowers. There are some very peculiar features about this flower. The lower lip of the corolla is withered and bent back just as in *Leonotis*. The two side halves of the upper lip, moreover, are bent downwards so that they touch one another, thus completely enclosing the anthers. The lever arrangement is very perfect: the short stout filaments of the stamens are about three lines apart, and this interval is completely blocked by the broad spoon-shaped barren lobes of the connective[1]. The style projects about one and a-half lines out of the upper lip, and is curved forwards. The nectary forms a sort of cushion two lines in diameter and one line high, on the top of which are the nullets.

I found this flower was visited by *Zosterops capensis* in the Cape Town gardens. I could see the process distinctly as it was within two yards, and cross-fertilisation is certain. I have also seen wild plants near Seapoint visited by birds (not Nectariniae) taking sips at the honey. I have never seen insects on it though I have watched it several days at different times for an hour or so, and it is probably truly ornithophilous like some other Salviae[2].

SARCOCOLLA SQUAMOSA, Bth.

The flowers are bright scarlet and closely packed together at the ends of the branches. Both the corolla-tube and involucral bracts are excessively viscid, so that insects are largely kept out.

The corolla-tube is about one inch long, and the free ends are scarlet and bent outwards. The stamens converge together and are united to one another and the style just below the stigma. When pushed apart by a needle a cloud of pollen is scattered from the anthers. The anthers in older flowers drop off outside the corolla as the stamens bend outwards till the anthers are beyond the corolla-tube. Honey is abundantly secreted by the base of the ovary.

[1] Each of these is one and a-half lines broad; there is an oblique depression on the inner side at the end of the filament. In the centre of this depression is a small peg attached to the connective.

[2] Cf. F. Müller, Bot. Zeit. xxviii. p. 274.

This flower I have often seen visited by *Nectarinia chalybea*, while insect visits are rare. Self-fertilisation is almost impossible from the superior position of the stigma.

The other species of *Sarcocolla* are almost certainly ornithophilous.

PROTEACEAE.

A large number of the species of *Protea* seem thoroughly adapted to bird fertilisation. The collection of the flowers into a head surrounded by closely fitting and frequently sticky involucral bracts forms a sort of natural drinking-cup. *Promerops caper* in fact appears to live almost entirely on the food so provided by the various species of this genus.

PROTEA INCOMPTA, R. Br. (Fig. 13.)

The involucral bracts in this species are peculiar. Their length increases from without inwards, and the most internal, which are five or six inches long, have their ends turned inwards, and as these bent edges are somewhat woolly, they form a convenient alighting place for the bird. The calyx shows the usual division into a narrow free sepal with a sterile stamen, and a portion formed by the union of the other three sepals bearing the three fertile stamens.

The calyx is expanded below the ovary, then narrows to a diameter of one line or so, while the last inch and a half is much wider and very hard and horny[1]. This last portion includes the anthers, which are closely pressed against the style. The anthers end in small scarlet barren extremities. These scarlet tips lie upon the stigmatic portion, and keep off the plant's own pollen. That part of the style which is in contact with the anthers has a peculiar structure (see Fig. 13).

It is marked by eight horny ridges which show a very strongly developed cuticular epidermis. The hollows between these ridges are occupied by the loculi of the anthers. When the free sepal is loosened from the other three by the elonga-

[1] This portion is in this species very woolly, thus keeping off insects.

tion of the style, the style is left with all this grooved portion covered with pollen. The minute stigma at the top cannot receive any of this pollen, although the separation of the sepals is almost explosive.

The bird, standing on the edge of the involucral bracts, dips its head repeatedly into the cup to suck the honey with which it is full. In so doing, it rubs against the rigid pollen-covered styles, and will also first touch several of the stigmatic extremities.

Both *Promerops caper* and *Nectarinia chalybea* act in this way, but the former is the commoner. Insects are also abundant, and no doubt assist in fertilisation. Very common forms are—

Diptera. *Camponotus niveosetosus*, etc.

Coleoptera. *Lytta nitidula*, and three other species which I have not been able to name.

PROTEA MELLIFERA, Thun. (Fig. 10.)

The heads are five inches long and two and a-half inches in diameter. The involucral scales are pointed and very sticky. The mode of fertilisation is similar to that of *P. incompta* [1].

Promerops caper very common on this species, and also *Nectarinia chalybea.*

Insects are also common, e. g.—

Coleoptera. *Anisonyx ursus*, ab., *Dichilus simplicipes*, *Scymnus*, sp., and four other species which I cannot name. I have also seen *Apis mellifica* flying round the heads and sucking the honey which exuded between the bracts.

PROTEA LEPIDOCARPON, R. Br.

Fertilisation almost identical with the preceding.

Visited by *Nectarinia chalybea.*

Insect visitors: Coleoptera. *Trichostella capensis*, *Platysoma capensis*, and six unnamed species.

[1] The ovary in this form is covered by a dense brush of beautiful golden brown hairs. I was unable to imagine the use of these hairs, as they are completely enclosed by the calyx, but I have often found the ovary destroyed by a beetle grub, and have no doubt that these hairs are to protect the ovary from its ravages.

PROTEA LONGIFLORA, Lam.

Visited by *Promerops caper*, near Houwhoek.

PROTEA GRANDIFLORA, Thun. (Figs. 11, 12.)

In this form the style elongates very greatly, and before it finally bursts the calycine envelope becomes greatly curved. When the separation finally takes place, the style straightens by its own elasticity, and a cloud of pollen is scattered. The stigma in this form is obliquely placed, while the furrows on the style are not so evident as in the other forms.

Visited by *Nectarinia*.

PROTEA CORDATA, Thun. (Fig. 16.)

I have not seen this species fertilised. The stigma lies in a minute slit at extremity of the style, while the anther-case has more the form found in *Serruria*.

PROTEA SCOLYMUS, Th.

Is quite similar to *P. mellifera*.

LEUCOSPERMUM CONOCARPUM, R. Br. (Figs. 17, 18.)

The flowers are closely packed together on the spherical capitulum. The bracts of all the flowers are well developed, and their ends are flattened out and modified somewhat like the bracts of a fir-cone. Out of the hemispherical surface formed by them projects part of the calyx and styles of the flowers. The cavities occupied by the bases of the flowers are narrow and much choked by a profusion of white hairs springing from the bracts.

The calyx ends in four horny lobes (all equal) closely applied over the end of the style. The anthers, opposite these lobes, are also attached to it. The end of the style is much swollen, but the swelling is pear-shaped (not cylindrical as in *Protea*), and scarcely grooved at all. At its narrow upper extremity are two slight horizontal ridges, between which lies the stigmatic slit. The pollen is shed all round the upper surface of the swollen style. It cannot fall

downwards, as the short filaments of the stamens are thickened in such a way that they completely embrace the lower half of the pear-shaped swelling (Fig. 18).

The style lengthens greatly after the calyx has attained its definite growth, and in consequence is thrown into a curved strained position. When it bursts the calyx, or is torn apart by the bird probing the flower, a slight explosion and scattering of pollen takes place.

Rather to my surprise, I saw a pair of the *Nectarinia chalybea* carefully going over the heads of this plant. They were catching insects, but appeared also to suck the honey. Beetles also visit the flowers, e. g. No. 173, *Pallena*, nov. sp., and a *Hedybius*.

L. hypophyllum, R. Br., and *L. diffusum*, R. Br., agree in all important points with the above species.

LEUCOSPERMUM NUTANS, R. Br. (Figs. 14, 15.)

In this form the style is further differentiated. The swollen end of the style instead of sloping upwards ends in a flat top, in the centre of which are two slight ridges protecting the stigmatic slit. The pollen is shed on this flat surface.

ANTHOLYZA AETHIOPICA, L.

The five lower perianth-segments are turned backwards, whilst the upper, which is larger than the others, forms a roof over the stamens.

The flowers are distinctly protandrous. All the stamens are turned so as to dehisce downwards, and the style branches subsequently unclose and move downwards between the stamens, so as to lie a little below the anthers.

Self-fertilisation is possible therefore if all the pollen has not been removed in the earliest condition.

After very tedious watching on different occasions, I was able to see birds at work on this flower, though not so clearly as I could wish. The length from stigma to base of ovary is sixteen lines, as usual in bird-flowers. Bees may often be

seen collecting pollen on this flower, and they may produce fertilisation, but the whole structure of the flower is ornithophilous.

A. prœalta, Red., is exactly similar to this species.

BABIANA RINGENS, Ker.

I am strongly inclined to place this amongst ornithophilous flowers, though I cannot certainly say I have seen the birds at work. The bright scarlet colour, the length (sixteen lines) from style to ovary, and the general appearance of the flower, are all in favour of its being ornithophilous, but I could never see the birds actually on the flowers.

NOTE ON HABITS OF CINNYRIDAE.

A point not, I think, usually known about the sunbirds is that they are excessively good fertilisers. They do not as a rule mix their honeys, but keep to one flower at a time in the same way as a bee. It is also easy to see how their habits arose. They are all in part insect-eaters. I kept *Nectarinia souimanga* in a cage for nearly six weeks, and found it was very expert in catching flies (unfortunately it died in the Red Sea on the way home), and there are all the degrees from several insect-eating birds, which only occasionally take a sip at honey, to the typical Nectariniae. *Zosterops virens* would in such a series be the connecting link in habit.

The most important species at Cape Town are *Nectarinia chalybea* and *bicollaris*, and *Promerops caper*. I found that *Promerops Gurneyi* replaces *P. caper* in the Eastern Districts of the Cape Colony and in Natal. *Nectarinia famosa* spends the season from December to April in the Karoo, while from December to April it appears to go to the Knysna and East London.

I am led to entirely disagree with Mr. Wallace's[1] opinion that the colour of flower-seeking birds is quite unconnected

[1] Wallace, 'Darwinism,' pp. 335, 336.

with their habits. As a matter of fact a peculiar shade of red found on the breast of *Cinnyris chalybea*, *C. afra*, *C. famosa*, *C. souimanga*, and *C. bicollaris*, is exactly the same as that which I found in the majority of ornithophilous flowers of South Africa. It is, moreover, not a common colour in flowers; and since Labiatae, Aloes, Irids, and Leguminosae all assume it when they become ornithophilous, some reason must be shown why the simple explanation given by Darwin should be set aside while no other is offered.

No one who has watched the male *Cinnyris* displaying himself in the sun can doubt that he has a distinct, even inordinate, knowledge of his own beauty.

The female apparently quite coincides with him; and considering that (as every one who has studied birds in the field admits) the sight of birds is relatively far keener than our own, Darwin's theory of sexual selection is quite satisfactory, and certainly deserves serious disproof by facts, not opinions.

EXPLANATION OF FIGURES IN PLATE XV.

Illustrating Mr. Scott-Elliot's paper on Ornithophilous Flowers in South Africa.

Melianthus major.

as, anterior; *ls*, lateral; *ps*, posterior sepal; *ap*, anterior, and *pp*, posterior petal; *hd* nectarial cup; *st a*, anterior, *st p*, posterior stamens; *o st*, rudiments of 5th stamen; *sty*, style; *ol*, lobes of ovary.

Fig. 1. Flower with four sepals removed.

Fig. 2. Longitudinal mesial section of flower in second stage.

Fig. 3. Stamens and style in third stage.

Erythrina caffra, D. C.

Fig. 4. Whole flower in first stage.

Fig. 5. Longitudinal section of basal part, vexillum being removed.

se, sepals; *ve*, vexillum; *al*, alae; *car.* carina; *sti.* stigma.

Sutherlandia frutescens.

Fig. 6. Whole flower with vexillum depressed as in fertilisation.

Fig. 7. Flower after sepals and vexillum have been removed.

Fig. 8. Flower with right half of vexillum, right alae and right half of carina removed before unclosure of vexillum.

Lettering as above, *h. r*, special ring of hairs round stigma; *p r*, pollen covered hairs.

Erica fascicularis.

Fig. 9. Flower in longitudinal mesial section; *n*, nectarial prominences; *ov.* ovary.

Protea mellifera.

Fig. 10. Single floret removed from head, natural size.

se_3, three united sepals; *s. sh*, sheath containing anthers *an*, and originally enclosing *cyl*, cylindrical grooved portion of (*sty*) style covered with pollen; *t*, hairy tip of sepals; *se.* odd sepal with barren anther ending in scarlet tip, *ti*; *sti*, stigma.

Protea grandiflora.

Fig. 11. Whole flower removed from head.

Fig. 12. Obtuse stigma.

Protea incompta.

Fig. 13. Section of cylindrical grooved part of style. *sk*, semicircular sclerenchymatous bands.

Leucospermum nutans.

Fig. 14. Whole flower.

Fig. 15. Longitudinal section through thickened end of style and sepaline sheath.

se, over-arching roof of sepals; *sta*, stamen; *p*, pollen; *fil*, filament thickened to clasp style; *sti*, stigmatic slit.

Protea cordata.

Fig. 16. End of style much enlarged.

Leucospermum conocarpum.

Fig. 17. Extremity of style much enlarged.

Fig. 18. End of sepal sheath with stigma enclosed by stamens and sepals.

Salvia aurea.

Fig. 19. Flower from side.

Fig. 20. Lever apparatus.

Fig. 5.

Fig. 16.

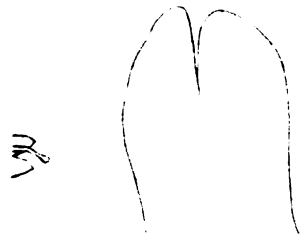


Fig. 13.

Fig. 17.

Fig. 20.

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Notes on Chondrioderma difforme and other Mycetozoa.

BY

ARTHUR LISTER.

With Plate XVI.

THE life-history of the Mycetozoa has been carefully worked out by De Bary, Cienkowski, and other naturalists on the Continent; they have described the emerging of the amoeboid swarm-cells from the spores, and their union to form the plasmodium, and they have told of the change of the plasmodium into sporangia.

There is difficulty in following this remarkable history in almost all the members of the group; the single species, which appears to stand apart as affording facilities for observation, and which has been more especially studied, is that which has received the name of *Chrondrioderma difforme*, although it is a great question whether it should not be classed under the genus *Didymium*, as proposed by De Bary (Mycetozoa, 1864).

I propose in the present paper to describe my observations on this species, and on some others where similarities or differences have presented themselves having relation to characters under consideration.

Chrondrioderma difforme is an inhabitant of rotting leaves; the sporangia may be met with in most seasons of the year, as chalk-white spots on fallen leaves which have accumulated in moist woods and shaded places; they vary in shape from hemispherical or flattened discs to irregular forms which may come under Rostafinski's term of plasmodiocarp, and in size

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from a fraction of a millimeter to 3–4 m.m. in diameter (Fig. 1).

Under ordinary conditions, the sporangium is found attached throughout its lower surface to a leaf by means of a membranous wall possessing a thickened margin of a more or less deep orange colour (Fig. 2). Adnate to this wall is a layer, usually of a purplish tint, which gives rise to the capillitium, and extends upwards as a delicate membrane enclosing the spore-cavity; numerous aggregations of chalk-granules are embedded between these two basal layers; outside the delicate upper membrane, and often extending on to the leaf slightly beyond the thickened margin, is a thin eggshell-like crust composed of crystals of calcium carbonate, usually closely compacted together. This outer calcareous wall is either attached to the upper membrane, or, less frequently, is separated from it by shrinking of the interior, and stands as a somewhat domed roof with a more or less considerable intervening cavity.

The capillitium extends among the mass of spores, connecting the lower with the upper part of the inner membrane, and consists of flattened threads, broad at their base and forking again and again into delicate extremities; the threads are sometimes filiform and anastomosing, either uniform or with expansions containing granules of calcium carbonate or refuse matter; they are often interrupted with dark bands or knots, such as are commonly seen in the capillitium of the genus *Didymium*. The colour of the capillitium varies from deep purple to pale yellow; or both the stout and delicate forms may be colourless. The spores measure 10–14 μ and are smooth, of a dark brownish purple colour; one side of the spore is usually thinner and paler in tint than the other, and is marked with a few reticulated dark lines. In drying, the paler side contracts towards the thicker and darker one, which retains its rounded form; it is along the lines of reticulation that the spore-wall breaks on the emerging of the swarm-cell.

In order to follow carefully the development of the

sporangia, I adopted a method of cultivation recommended by Professor Bayley Balfour. Wet blotting-paper was placed on a plate and sprinkled over with some seeds of garden cress; with these were sown the spores from a single sporangium of *Chondrioderma difforme* collected in a shady wood, and the cultivation was covered with a bell-jar. A similar preparation was also made with the spores from a sporangium taken from a heap of leaves on my premises; the sporangia of both cultivations (which I will call respectively A and B), showed well-developed capillitium, but the former was of a bolder and darker type than the latter.

In the course of twelve days several small yellow plasmodia with diverging veins were observed on the blotting-paper sown with the spores of sporangium A, and on the following day one of these had contracted into an orange-coloured hemisphere about 1 m.m. in diameter, which became dark purplish brown in the course of the day; next morning it was grey, changing to the usual chalk-white when dry. On examination, the spores were found perfectly mature and normal; the capillitium, though less abundant than in the parent, was fairly pronounced, and the thickened margin of the base of the sporangium was of the same dark orange colour as in the original gathering.

In the meantime fresh sporangia were rapidly appearing, and in three weeks from the date of sowing, two hundred and fifty sporangia were counted on the roots and stems of the cress and on the blotting-paper.

A small plasmodium from this cultivation was carefully lifted, together with a few fibres of the blotting-paper, and placed on a glass slide for examination under the microscope. The rhythmic streaming was clearly observed, and it was evident that the yellow colour was due to the minute protoplasmic granules and not to foreign matter in suspension; it was afterwards placed under a wine-glass, where it formed into a sporangium in a few hours.

Under the bell-jar, covering the spores from cultivation B, sporangia made their appearance in twelve days, and

increased in number in the same manner as in the other experiment; but these differed from the first in having the plasmodium almost entirely colourless and the bases of the sporangia only faintly tinged with yellow.

A subsequent cultivation was made with cress-seeds and the spores from a sporangium with strikingly dark capillitium (Fig. 4 *a*). In the course of 11 weeks 310 sporangia were produced on the blotting-paper and cress-stalks; the capillitium in these varied in tint from that of the parent to colourless, and in amount from abundance to scarcity. (Fig. 4 *b* and *c*.)[1]

In order to ascertain whether the time of the development of sporangia depended on the condition of the young cress-plants, three pieces of wet blotting-paper were sown with cress-seeds on the same day, and covered with bell-jars. The spores of three sporangia from the cultivation producing 310 fruits were sown; those from one at the same time as the cress; from another four days after, when the seeds had sprouted; and from the third eight days after the cress was sown. In the first, a sporangium appeared on the thirteenth day, on the following day there were three; the numbers increasing day by day to 5, 20, 24, 40, 80, 125. Under the second bell-jar, three sporangia appeared twelve days after the spores were sown or sixteen days after the cress. The daily increase in numbers was as follows, 5, 10, 20, 40, 50. Under the third, four sporangia were seen on the tenth day from sowing the spores, but the blotting-paper was allowed to become too wet, which checked further increase.

[1] In subsequent examinations of many sporangia from this large cultivation, the spores were usually found to be of the normal size and dark purple brown in colour, but in a few they were pale violet, and varied much in form and dimensions. I had little doubt that these were imperfectly developed, and that I should find, as I have often done in other species when the spores have not properly matured, that germination would not take place. To test the point a large number were placed in water under a cover-slip; next morning almost all had hatched, large and small, regular in form and irregular, the swarm-cells were as vigorous as those from the dark spores, and in a few days many had coalesced into young plasmodia.

I have frequently met with considerable difference of colour in the spores of some species f *Didymium* and *Stemonitis*, but not to the extent exhibited in this case.

From these, and many other experiments, it appears that sporangia of *Chondrioderma difforme* form from ten to fourteen days after the spores are sown with cress-seeds. The most rapid development I have met with was in an experiment with green unripe seeds of *Plantago lanceolata* which had been steeped in water for several hours; seven of these seeds were placed on wet tissue-paper in a watch-glass with spores from cultivation A: on the ninth day a sporangium was formed, and near it a branching yellow plasmodium showed active streaming movement; many more sporangia developed during the next few days [1].

I have tried other seeds with mucilaginous testae without obtaining sporangia, though no doubt there must be some as favourable to their growth as the above.

Cienkowski's experiment, in which plasmodia appeared four days after sowing the spores, and sporangia on the following day [2], would seem to be an exceptional experience.

The following observations relate to further details of development. Spores from two small sporangia from the cultivation A, each containing capillitium in fair abundance of the type of Fig. 3, were sown with seven cress-seeds on a ring of blotting-paper in a watch-glass. In eighteen days, 10 sporangia had ripened on the cress and on the paper. The plasmodium was of the same yellow colour as in the former generation, but the sporangia showed a marked difference in the capillitium. Some were repetitions of the parents in all respects; others contained only a few threads, and these varied in colour and thickness, and one, though equalling the parents in size, had no capillitium whatever. The spores, as a rule, were well developed and only varied in size from 10 μ to 14 μ; but in some sporangia many were abnormal, measuring from 20 μ to 40 μ, others were still larger and of irregular form; but this variation in the size of the spores always occurs, in every species I have cultivated, when grown under unfavourable conditions.

[1] I need hardly say that as good results are obtained when ripe plantain-seeds are used.

[2] De Bary, Fungi, Mycetozoa, etc., Eng. ed. p. 433.

Another sowing of spores from the cultivation B was made in two watch-glasses on tissue-paper with three and four cress-seeds. In ten days plasmodia were detected, almost hyaline in colour; the thin tissue-paper allowed the streaming movement to be observed under the microscope very clearly.

In a few days from this time, eight sporangia had formed in each watch-glass, and these varied like the last described in having the capillitium well developed or absent and either darker than that of the parent or colourless. The basal wall was in some cases almost free from colour, in others it had nearly as much orange tint as many that had formed from the yellow plasmodium [1].

Some sporangia formed under water at the bottom of the watch-glass, and here there was no development of the calcareous upper wall, or it was represented by a few scattered crystals; in point of fact exactly resembling those described by Professor Marshall Ward as growing on the submerged roots of hyacinth [2].

A curious intermediate form was noticed in some sporangia which had developed when partly covered with water: in these the chalk was distributed in irregular patches over the inner membrane and was overspread by an outer membrane, giving a tough character to the sporangium; thus a double membraneous wall was formed embracing the whole spore-cavity, the patches of chalk lying, as it were in pockets, between the two layers. From the base of one of these sporangia arose irregular columns, or lumps of aggregated chalk-granules enclosed in diverticula of the inner membrane, and taking the place of normal capillitium; in another, one

[1] The varied colour of the plasmodium is interesting in relation to what we find in different gatherings of *Trichia fallax*. In the neighbourhood of Lyme Regis, where this species is very common, it rises out of decayed wood, either in rose-coloured or pure white plasmodium. As a rule, we do not find these colours mixed together; on one stump all will be red, on another all white. The sporangia, capillitium, and spores appear to be perfectly identical, whether developed from the red or white plasmodium.

[2] Studies from the Biological Laboratories of Owens College, vol. i, Pl. III.

or more of these columns formed the base of a capillitium-thread, in another again they were mixed with threads of the usual kind.

Similar aggregations of chalk-granules in the basal portion of the capillitium are not unusual in *Didymium squamulosum.*

Besides the method of cultivation already described, the spores of many Mycetozoa may be caused to germinate under a cover slip on a glass slide, or in a hanging drop, a plan given by Professor Marshall Ward (loc. cit.). A pad of a few thicknesses of blotting-paper with a hole about $\frac{3}{4}$ inch in diameter is wetted and laid on a glass-slide, a drop of water containing spores is placed on a square cover-slip and inverted over the central opening; the spores are thus kept in a moist chamber allowing access of oxygen through the porous substance of the blotting paper, while the wet pad prevents the drop from drying. Experiments with this method will be referred to hereafter.

The time that spores take to germinate varies greatly not only in different species but in different gatherings of the same species. Those of a specimen of *Stemonitis fusca* gathered in the autumn of 1888 produced swarm-cells in abundance within an hour and a half of their being placed in water under a thin cover-slip; after six months' preservation, they germinated almost equally quickly, and after thirteen months, although they took a longer time, vast numbers of swarm-cells were hatched within twelve hours. Another gathering of the same species in the spring of 1889, examined at the time of collecting, began to germinate in four hours, and in twelve hours nearly all the spores had hatched. In other gatherings germination did not begin until twelve hours, and after several days many spores were still unburst. In others again, though well ripened and in fine condition, I have not succeeded in obtaining swarm-cells at all.

The large spores of *Amaurochaete* germinate in from two to four hours, and this is but little delayed after they have remained for a year and a half in a cabinet.

The spores of *Ceratium hydnoides*, gathered more than a year ago, still give birth to their remarkable swarm-cells abundantly, in about twelve hours after being placed in pure rain-water[1].

With many other species I have had similar results, germination taking place in from six hours to several days, but with some I have failed altogether. My experience with *Stemonitis fusca* leads me to suppose that in these last I may only have been unsuccessful in obtaining favourable specimens. Nearly all my experiments have been made with filtered rain-water.

The conditions under which the spores are placed have a marked influence on the development of swarm-cells. Thus the spores of the specimen of *Stemonitis fusca* above mentioned, where germination takes place rapidly, will remain at the bottom of a test-tube half filled with water for many days, if not permanently, without germinating, while if some of these spores are taken out of the test-tube where they have lain for some days, and placed by means of a pipette under a cover-slip on a glass slide, the swarm-cells appear in the course of an hour or two. This has been the case with several other species which I have treated in the same manner, though it is by no means a constant rule.

Arcyria punicea, *Perichaena corticalis*, *Badhamia panicea* and some others have germinated almost equally rapidly under a cover-slip, in a hanging drop, or at the bottom of a test-tube.

In the numerous gatherings and cultivations of *Chrondrioderma difforme* which I have examined, the spores have been very constant in the time they take to hatch. Under a cover-slip or in a hanging drop the swarm-cells begin to emerge in six to eight hours. Although deep immersion delays, yet it does not prevent their germination.

The following experiments relating to the formation of plasmodium under a cover-slip and in a hanging drop fur-

[1] De Bary mentions (loc. cit., p. 448) that the spores of *Ceratium* do not germinate in pure water, but only in a suitable nutrient solution.

nished some points of interest. I may mention that in preparing spores for cultivation, a drop of methylated spirit is first applied to expel the air from among them and water is immediately added; the spirit does not appear to have any injurious effect, for even minute spores, such as those of *Lycogala*, germinate freely after the process.

Spores of *Chondrioderma difforme* prepared in this manner were covered with a thin glass square, supported on one side to prevent pressure. In a few hours swarm-cells were produced, and increased rapidly by division for some days, when a large number changed to microcysts, the resting stage described by De Bary[1], and a great proportion of the remainder assumed a sluggish amoeboid condition. After an interval of several days a number of the amoeboid bodies were seen to unite and form small plasmodia; their nuclei were observed to remain distinct after many had coalesced (Fig. 5).

The plasmodia increased daily in size and numbers. I once observed two approach each other with very slow movement (Fig. 6); there appeared to be no mutual attraction until they were only separated by a distance of 40 μ, when a lobe from one was pushed out towards its companion, the intervening swarm-cells were thrust aside, and they came into contact; the hyaloplasm of each blended at a single point, and a thin stream of granular matter was seen to pass, then with a return flow of the streaming in the larger of the two the channel was widened and a gush of its contents poured into the smaller one, when union was complete, and the system of circulation became common to both (Fig. 7).

Many microcysts were incorporated by the plasmodia (Figs. 6 *a* and 7 *a*), and lay enclosed in vacuoles for three or four hours, during which time they became gradually and entirely assimilated—the sluggish amoeboid cells were often seen to be absorbed in the same manner. Thirteen separate plasmodia were counted in the preparation, and no other instance of union between them was seen to take place during the thirty-five days that the observation lasted.

[1] loc. cit., p. 427.

The form and character of the plasmodia were the same as given by Professor Marshall Ward, and so well described by him in the volume before mentioned (Pl. V).

In a cultivation in a hanging drop, fifty-two small plasmodia were counted distributed over the convex surface four days after sowing the spores in a drop of rain-water. In this experiment it was noticed that the young plasmodia exerted an attracting influence over the surrounding swarm-cells in a more evident manner than under the cover-slip. The coalescence of amoeboid swarm-cells was observed as in the former case, but no union of plasmodia was seen to occur; several of the latter became encysted with a double membranous envelope of a faintly yellow tint, somewhat corresponding with those described by Zopf[1].

Although no sporangia were produced in these experiments, in which only pure water was used, in six subsequent cultivations in hanging drops, when portions of the mucilaginous testa of cress or plantain seeds were added, well-formed sporangia with characteristic capillitium and spores made their appearance in about a fortnight after sowing the spores.

In tracing the development of these sporangia the following observations were made. The spores hatched the day after sowing. The plasmodia began to form on the fourth day; they increased in size during the three following days, but retained the same nearly hyaline appearance as at first; they were slightly turbid with faint protoplasmic particles. On the seventh day minute refracting granules of calcareous matter appeared for the first time; on the eleventh day the calcareous granules were larger and more numerous, showing conspicuously in the streaming currents; on about the fourteenth day a sporangium was formed, usually at some point where it was exposed to the air, and in this case the calcareous wall was fully developed; some minute sporangia which formed under water had no calcareous wall or capillitium though the spores were perfectly normal.

The calcareous matter is discharged from the plasmodium

[1] Encyk. der Nat. Wiss. 1ste Abt. 41 Lief., p. 170.

immediately after it has taken the sporangium-form. On one occasion this change was closely watched in the case of a submerged sporangium; the chalk granules were at first distributed over the surface, but in a short time they slipped off and were deposited in a little heap at the side.

On another occasion, when possibly some movement had produced a rupture in the soft wall of an immersed sporangium, a portion of the spore-plasma protruded through the rent, and was observed to branch into lobes and to divide into spores in the same manner as was noticed in the spore-formation of *Brefeldia maxima*, described in Annals of Botany, Vol. II. p. 18; each young spore, on constricting itself off, contained for a time a fluctuating vacuole, as was observed in the case of *Brefeldia*.

The species most closely allied to *Chondrioderma difforme* appears to be *Didymium dubium*, which differs chiefly in the character of the outer wall and in having smaller and paler spores and a more profuse capillitium. The plan of the sporangium is precisely the same, and it has the same isolated habit; it is only recorded in Saccardo's Sylloge Fungorum as occurring in Bohemia, but is fairly abundant among dead leaves in one locality near Lyme Regis. It is interesting in connection with the subject of this paper in being liable to much variation.

The typical spores are nearly or quite smooth, of a pale violet-brown colour, and measure 7–9 μ, but specimens are not infrequent with large spores nearly uniform in size, the extremes ranging from 12–15 μ, and distinctly echinulate. The capillitium is dense, dark, and rigid, anastomosing at the extremities, but it is sometimes delicate and flexuose, though always coloured. The outer crust is a loose aggregation of large and very beautiful stellate crystals, but now and then we find it closely compacted, with but slightly crystalline character, and nearly resembling that of *Chondrioderma difforme*. I have not succeeded in obtaining the plasmodium of *Didymium dubium* from a cultivation of the spores in a hanging drop or with cress-seeds on blotting-paper, although

the swarm-cells make their appearance in great abundance. The plasmodium is very inconspicuous. I have had dead leaves kept wet under a bell-jar, among which it must have crawled for many days, but, though carefully watched, the first indication of its presence was the appearance of a pale young sporangium, which developed into the normal form.

The only species, besides *Chondrioderma difforme*, with which I have obtained plasmodium in a hanging drop is *Stemonitis fusca*. Swarm-cells appeared the day after sowing the spores, and in twelve days a small plasmodium was seen; this increased to considerable dimensions, principally, as it appeared, by the absorption of microcysts, as described p. 9, but at the end of a fortnight it changed into macrocysts without further development. This plasmodium exhibited several curious peculiarities as compared with that of species found on dead leaves, etc., which may perhaps be owing to its natural habitat being the substance of rotten wood.

At a meeting of the Linnean Society, in April, 1889, I described the mode of feeding which I had observed in the swarm-cells of *Stemonitis fusca*. I have since been able to watch the same process in the swarm-cells of several other species. Those of *Perichaena corticalis* afforded an interesting instance, because of the great activity of the bacilli which abounded in the preparation, and as showing the voracity of a few individual swarm-cells. One was noticed which already contained four vacuoles stuffed with bacilli, probably six to eight in each. It was observed to throw out several long pseudopodia from the posterior region, to which active bacilli became attached. In the course of twelve minutes four were seen under a Beck's $\frac{1}{10}^{th}$ immersion lens to be drawn in and conveyed into freshly formed vacuoles.

I have repeatedly seen bacteria taken by swarm-cells of *Chondrioderma difforme* in the manner above described, and it would appear that bacteria form their principal food[1]. On one occasion I had a favourable opportunity for observing the

[1] The vacuoles in the plasmodium of *Chondrioderma difforme* are frequently seen to contain bacteria.

digestion of bacilli on account of the quiescent state assumed by a swarm-cell, which remained with little active movement for an hour and a half. On the previous evening I had placed some spores of *Chondrioderma difforme* in water under a thin cover-slip; on the following morning swarm-cells were in great abundance in the pure water. I introduced a drop containing multitudes of bacilli from a glass in which a piece of *Stereum hirsutum* had been soaking for several days. In a short time a number of the swarm-cells were seen, attended by bacilli, some of which were attached to their pseudopodia, and some were already enclosed in vacuoles. The swarm-cell in question had taken an amoeboid form, occasionally producing and again withdrawing the cilium, while from time to time thin pseudopodia were extended from the opposite end, but more frequently the posterior region expanded into a somewhat funnel-shaped mouth. Into such an expansion a stout bacillus about 2 μ long was seen to enter; in the course of a few seconds it was enclosed with a noticeable amount of water, by the folding over of the lips of the funnel, and conveyed into the body-substance; a few minutes after, another bacillus was taken in, much in the same manner, but no globule of water was introduced. Ten minutes later a large bacillus 4 $\mu \times 0{\cdot}75\,\mu$ was caught by a prolongation of one side of the funnel, and in the course of half a minute a tube-like extension of protoplasmic substance invested the bacillus, and it was drawn in (Fig. 8). It remained for a short time in direct contact with the granular matter of the body, but was soon surrounded with an oval vacuole (Fig. 9). The swarm-cell continued inactive for nearly an hour, when it assumed an extended form, and shortly after swam away with rapid jogging movement (Fig. 10). Constant observation was maintained during this hour, and the bacilli were seen gradually to dissolve in the vacuoles in which they lay, until at length all trace of them had disappeared together with their containing vacuoles, and only the contracting vacuole remained in the homogeneous granular substance of the swarm-cell.

At the commencement of the observation this granular

protoplasm was much more turbid than at the close, when it was remarkably hyaline; the swarm-cell appeared also to have increased in size, though this was difficult to determine by measurement in consequence of its changing form. No rejection of refuse matter took place while the observation lasted.

In the same preparation I watched a swarm-cell creeping in a straight line with the strange snail-like movement, so difficult to understand. In its course it came to a small group of motionless bacilli lying against the glass; immediately it changed its linear form and spread itself out, covering four of the bacilli. In about two minutes it resumed its former shape and movement and crept away carrying off two of the bacilli in vacuoles.

These observations seem to confirm the opinion of De Bary that the organisms under consideration should be classed among the animal rather than the vegetable kingdom, which led him in 1858 to adopt the term Mycetozoa in place of that of Myxomycetes for the group. When a creeping swarm-cell is watched, with the projecting cilium placed immediately in advance of the nucleus, which never shifts its position, and when, as in the last-mentioned case, we note the manner in which the vibrating extremity of the cilium appeared to detect the presence of the bacilli before the swarm-cell spread itself over them; again, when we observe the creeping action suddenly change, and raising itself from the decumbent attitude, with a few lashing strokes of the cilium the swarm-cell releases its foot-hold and swims away; and when to these remarkable movements is added the process of ingestion which has been described; we cannot but feel the force of the conclusion at which De Bary arrived, if indeed a distinct line of demarcation between the two kingdoms can be said to exist.

Another point of interest which these experiments bring out is the variation which occurs in the progeny of a common parent when the natural conditions are slightly altered by cultivation.

The calcareous wall of the sporangium may be either closely

compacted, or composed of stellate crystals loosely combined; it may be scattered in patches and enclosed in a double membrane, or may be entirely wanting.

The capillitium may be well developed, composed of stout forking threads, or may be of delicate form (a variation shown as strikingly in *Didymium dubium*), or it may be absent altogether, and the spores may vary both in colour and dimensions.

The colour of the membranous wall of the sporangia, as well as of the threads of the capillitium, varies widely in different fruits of the same stock, and there is often a slight though well-marked difference of colour in the plasmodia.

When these varying characters are seen in the one species in which the life-history has been followed through successive generations, one is led to anticipate that if methods should be discovered for cultivating other kinds which have hitherto baffled our endeavours, we should find that many closely allied forms which are at present considered as distinct species, may be traced to a common parentage in this most variable group.

The following is a list of species in which I have observed the formation of sporangia from the plasmodium, with the colour of the latter appended. A large proportion of these were obtained by collecting rotting leaves on which plasmodium was seen, or betrayed by the peculiar odour attaching to it; they were preserved under bell-jars and frequently supplied with fresh rain-water, and, after some weeks of little promise, unexpected sporangia would often make their appearance on the leaves.

Species.	Colour of Plasmodium.
Amaurochaete atra	yellowish white.
Arcyria cinerea	greyish white.
—— *ferruginea*	rose.
—— *incarnata*	white.
—— *nutans* (buff variety)	white.
—— *nutans* (red variety)	white.
—— *punicea*	white.

Species.	Colour of Plasmodium.
Badhamia panicea	greyish white.
—— *utricularis*	orange yellow.
Brefeldia maxima	pure white.
Chondrioderma difforme	white to orange yellow.
—— *Michelii*	opaque white.
—— *spumarioide*	watery white.
Clathroptychium rugulosum	rose.
Comatricha Friesiana	watery white.
—— *typhina*	watery white.
Cornuvia metallica	colourless.
Craterium aureum	lemon yellow.
—— *leucocephalum*	yellow.
—— *vulgare*	yellow.
Cribraria argillacea	lead coloured in rising sporangia.
—— *aurantiaca*	sap green.
Diachaea leucopoda	white.
Dictydium cernuum	purple in rising sporangia.
Didymium clavus	grey.
—— *dubium*	colourless.
—— *microcarpon*	brownish grey.
—— *squamulosum*	watery white.
Enteridium olivaceum	rose.
Fuligo varians	yellow.
Hemiarcyria rubiformis	purple in rising sporangia.
Lamproderma iridea (Cke.)	colourless.
Lycogala epidendrum	rose.
Physarum compressum	greyish white.
—— *leucophaeum*	watery white to greenish.
—— *leucopus*	opaque white.
Reticularia lycoperdon	white.
Spumaria alba	white.
Stemonitis ferruginea	lemon yellow.
—— *fusca*	white.
Tilmadoche mutabilis	yellow.
Trichia affinis	pure white.

Species.	Colour of Plasmodium.
Trichia fallax	white and rose.
—— *varia*	white.

The plasmodium of most species inhabiting dead leaves is discoloured by foreign matter in suspension until a short time before the change to sporangia takes place.

EXPLANATION OF FIGURES IN PLATE XVI.

Illustrating Mr. Arthur Lister's Notes on *Chondrioderma difforme* and other Mycetozoa.

Fig. 1. Two sporangia of *Chondrioderma difforme* on elm leaf, showing outer calcareous and membraneous walls. × 40.

Fig. 2. Base of sporangium, the spores removed, showing fragment of calcareous wall (*a*), attached to thickened margin (*b*), with capillitium springing from the membranous inner wall (*c*). × 100.

Fig, 3. Capillitium of usual character in well-developed specimens.

Fig. 4. (*a*) Capillitium of sporangium from elm leaf, the spores of which were sown on blotting-paper with seeds of garden cress. 310 sporangia were developed in this cultivation during eleven weeks; (*b*) capillitium from one of these sporangia in which the threads were abundant; (*c*) capillitium from a cluster of four from the same cultivation, in each of which the threads were very scanty and colourless.

Fig. 5. Early formation of plasmodium, the nucleus of each of the swarm-cells of which it is composed remaining distinct.

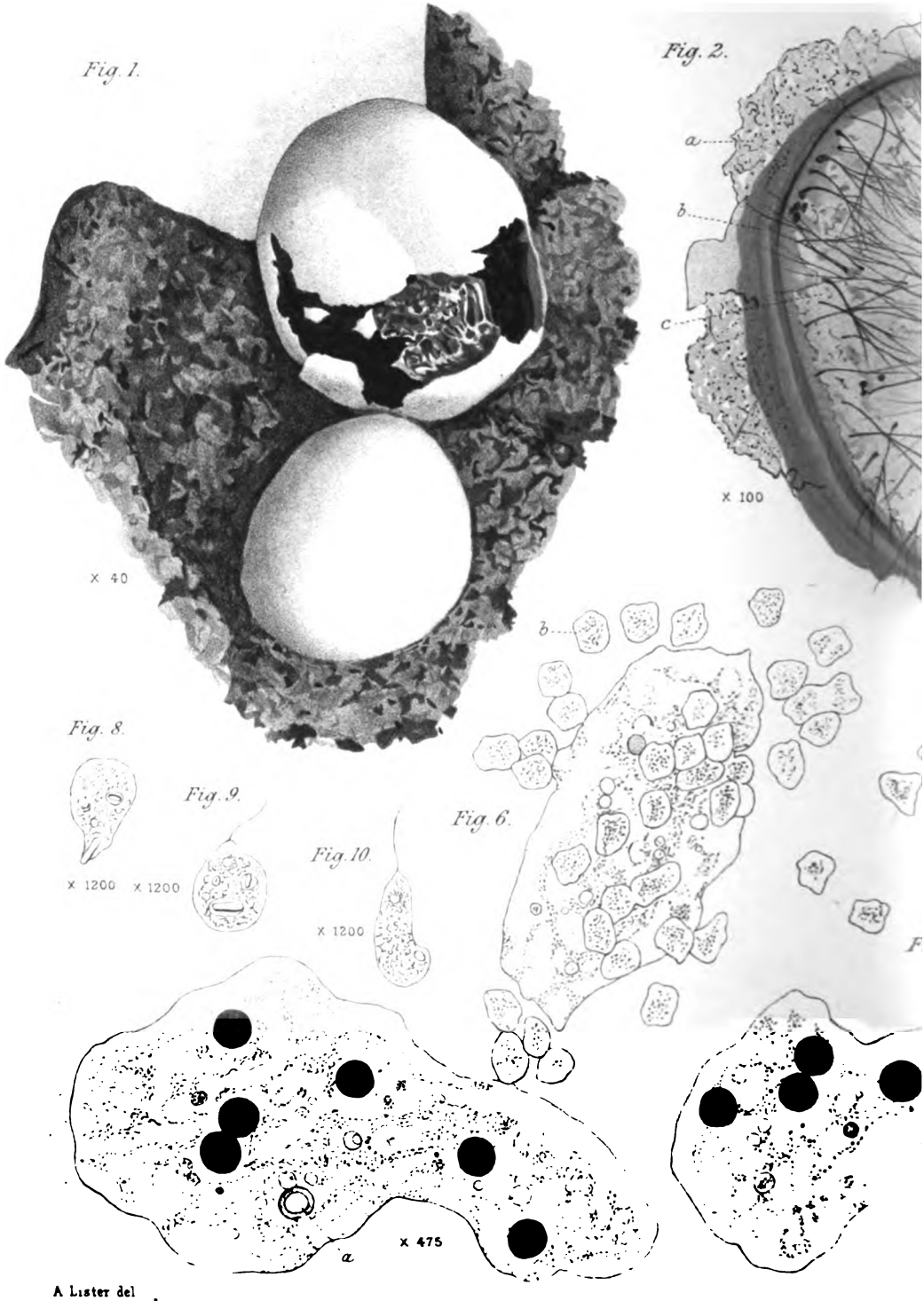
Fig. 6. Two plasmodia approaching each other and about to coalesce: in one of them six spores are temporarily incorporated: (*a*) a microcyst enclosed in a vacuole, (*b*) amoeboid swarm-cells and microcysts.

Fig. 7. The two plasmodia after coalescence, drawn ten minutes after Fig. 6.

Fig. 8. Swarm-cell with the cilium withdrawn, embracing a bacillus, two smaller bacilli having been ingested a few minutes previously.

Fig. 9. The same swarm-cell with bacillus enclosed in a vacuole.

Fig. 10. The same after an interval of an hour having resumed active movement, the bacilli and their enclosing vacuoles having disappeared.



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LISTER.— ON CHONDRIODERMA DIFFORME.

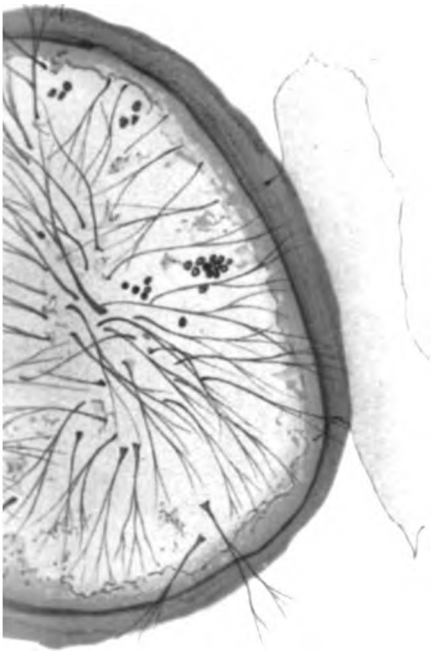
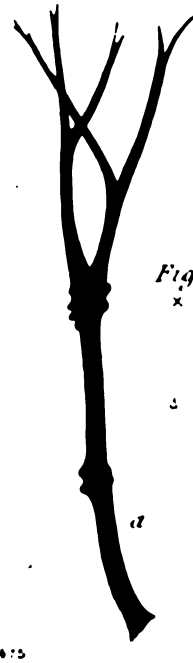


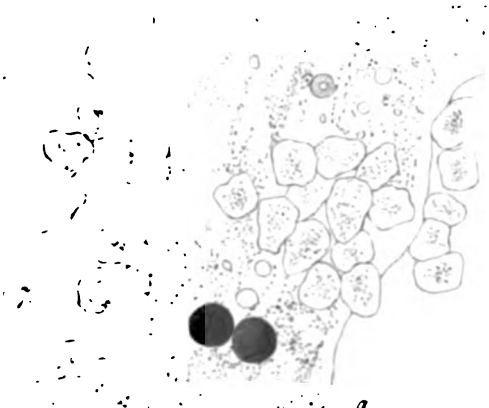
Fig. 3
× 350

b



a

Fig. 4
× 350

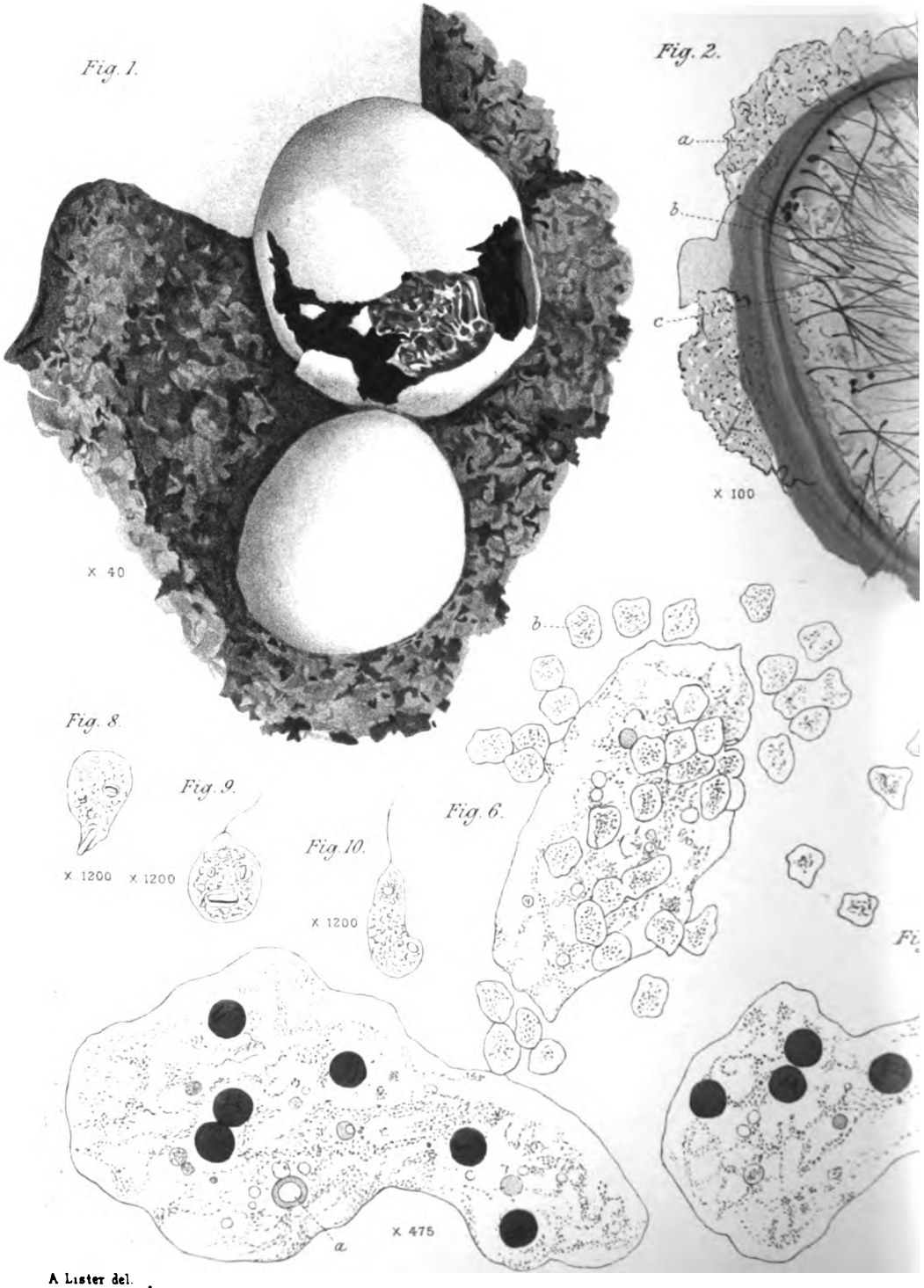


a

Fig. 5

× 475

× 475



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LISTER.— ON CHONDRIODERMA DIFFORME.

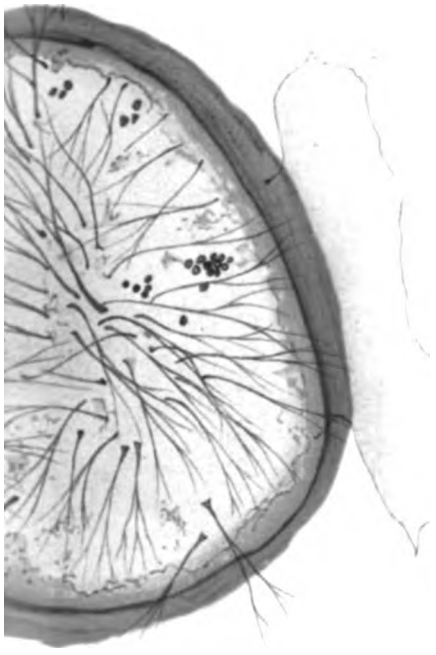


Fig 3.
× 350

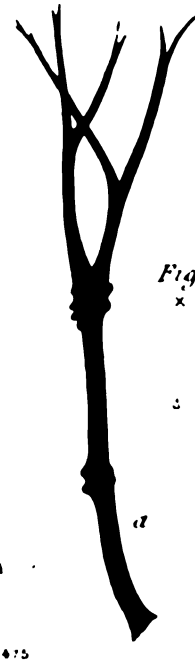


Fig 4
× 350

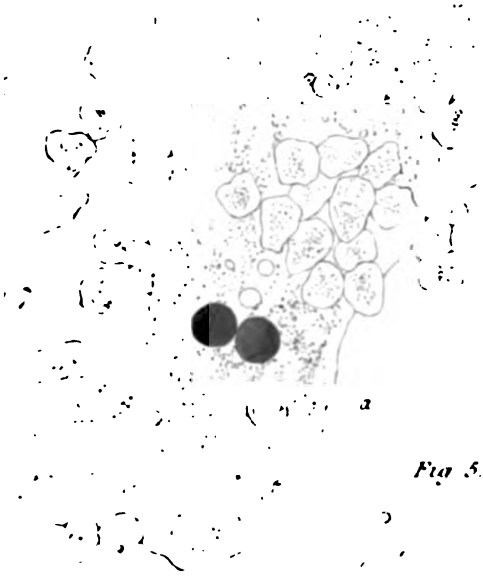


Fig 5.

× 475

× 475

NOTES.

ON CORTICAL FIBRO-VASCULAR BUNDLES IN SOME SPECIES OF LECYTHIDEAE AND BARRINGTONIEAE.—The following abstract requires a word of prefatory explanation. In 1883 I noted the peculiarity described in two species of *Gustavia* growing and fruiting in the plant-houses at Cork. Having obtained seedlings I made a fairly full study of the anatomy of these plants in 1884, and kept my results by me in the hope of being able to extend them to all the types of the group. I soon found this impossible at Cork, and learning that Dr. Lignier[1] (now Professor at Caen, then assisting Professor Bertrand at Lille) was at work on the Myrtaceae, with ampler opportunities, I handed him over my materials, only publishing enough to show my chief results and deductions at the Birmingham meeting of the British Association in 1886. Since then I have been repeatedly asked for copies of my note, and as Lignier does not fully adopt my view as to the origin of the bundles, I have thought it advisable, with the kind sanction of the Editors of the 'ANNALS OF BOTANY,' to disinter it from the Report and reprint it here with a few slight emendations all clearly marked off within square brackets.

'*On Cortical Fibro-vascular bundles in some species of* Lecythideae *and* Barringtonieae.—Accessory fibrovascular bundles are usually connected with abnormalities of vegetation, and probably serve chiefly to ensure continuity of the phloem under pressure [the abnormality of arborescent sp. of *Strychnos* is to be regarded as due to reversion from climbing ancestors]: hence it is interesting to note their occurrence where this explanation is inadmissible. In *Gustavia* and *Lecythis* belonging to the sub-order Lecythideae of Myrtaceae there is a complete system of cortical bundles external to the pericycle, anastomosing with the leaf-tracks [of the central cylinder] at the nodes. These

[1] Recherches sur l'anatomie comparée des Calycanthées, Melastomacées, et Myrtacées, Archives Botaniques du Nord de la France, iii. 1887.

bundles have often a complete circle of exogenous wood, without pith, and a crescent of phloem on the outer side; they are all but concentric [and may become so by the extension of the phloem]; in the petiole it is impossible to distinguish the bundles [proceeding from the central cylinder][1] from the cortical set owing to the anastomoses in the nodes. The section of the petiole with its scattered bundles recalls that of a monocotyledonous stem, but there is no pericycle.

'In *Stravadium dracemosum*, belonging to the closely allied Barringtonieae, there are similar bundles, but the orientation of the liber is reversed, and the bundle [derived from the central cylinder][2] retains its distinctness in the petiole.

'The explanation is suggested by the following facts. The cataphyllary first leaves of *Gustavia* [and *Lecythis*] are decurrent to the node below, so that the stem is winged, and the wings contain one or two pairs of accessory common bundles. Higher up the wings are lost, but their vascular bundles remain to give rise to this system of accessory bundles [I therefore refer the bundles to the decurrent wings probably present in the ancestral forms, but which have merged into the stem in existing forms save in the first formed internodes of the seedling]. *Napoleona* has a similar system of cortical bundles; [this confirms the view that its proper systematic position is next the Barringtonieae].'

MARCUS M. HARTOG, Cork.

VAUCHERIA-GALLS.—Professor D. Oliver has been kind enough to call my attention to an item in the literature of this subject overlooked both by Benkö and myself (Annals of Botany, vol. iv. No. 13), viz., a paper by Professor Oliver in the 'Transactions' of the Tyneside Naturalists' Field Club, vol. iv for 1860, p. 263, with an admirable plate. The species of *Vaucheria* is not given; the imprisoned animal is stated, on the authority of the late Mr. Gosse, to be probably *Rotifer vulgaris*. Morren's paper, in the Bull. Roy. Acad. Bruxelles, vol. vi. No. 4, is also illustrated: there is a translation, but without the figures, in Ann. Nat. Hist., vol. vi. p. 344.

In a paper read before the Liverpool Microscopical Society in

[1] By a slip I wrote here 'common bundles.'

[2] 'Common bundle' in the original.

December, 1889, is an account of the 'galls' observed in *Vaucheria dichotoma* by Mr. W. Narramore, F.L.S., accompanied by a good plate. The parasite is described as *Notommata Werneckii*. Mr. Narramore found it infesting the main filament as well as the peculiar outgrowths, which he regards, in this species, not as hypertrophied oogones, but as independent outgrowths from the main filament.

ALFRED W. BENNETT, London.

On Sarcodes sanguinea, Torr.

BY

F. W. OLIVER, B.A., D.Sc.,

Quain Professor of Botany in University College, London.

With Plates XVII, XVIII, XIX, XX, XXI.

THE family of the Monotropeae presents many problems to the botanist, not only on account of the remarkable habit of growth and mode of nutrition of its members, but also in view of its curious distribution and affinities. Any addition to our knowledge of such a group will be, then, not without value, even if it serve only as a contribution to a biological and systematic monograph of the whole order by some future worker. Of the eight genera [1] of the order all, with the exception of *Monotropa* and *Cheilotheca*, are limited in their distribution to North America; *Monotropa* being spread widely throughout the whole north temperate zone, and *Cheilotheca* being found only in the Himalaya. With the exception of *Monotropa*, little is known of these forms beyond the bare descriptions, which are often imperfect. Nor, on account of their peculiar mode of growth, has it been possible, so far, to cultivate these plants successfully in our botanic gardens. In view of this general obscurity in which so many of the genera remain, it has long been desirable that an investigation should be made into the general morphology and mode of life of such of them as should be available.

[1] *Allotropa*, *Monotropa*, *Pterospora*, *Sarcodes*, *Schweinitzia*, *Newberrya*, *Pleuricospora*, and *Cheilotheca*.

[Annals of Botany, Vol. IV. No. XV, August 1890.]

When then, in the autumn of 1888, some very fine specimens of *Sarcodes sanguinea*, in excellent preservation, were presented to the Royal Gardens, Kew, by Messrs. F. D. Godman and Elwes, it was most willingly that I undertook, at Mr. Thiselton Dyer's kind suggestion, to work through the plant and have a portrait of it executed by a competent artist.

In the present paper I confine myself almost entirely to a description of *Sarcodes* without entering into any discussion as to the affinities of the order *Monotropeae*, or into any history of the various memoirs bearing on the morphology of the other genera. In the important contributions by Drude[1], and by Kamienski[2], sufficient references will be found.

Sarcodes sanguinea, Torr., the 'Snowplant' of California, was first described and figured by Torrey[3] in the 'Plantae Frémontianae,' and later, indifferently, by Chatin[4] in his 'Anatomie.' The only other representation that I know of it is a sketch by Miss Marianne North in her gallery of flower paintings in Kew Gardens. This shows the plant amid its natural surroundings of snow and pine-woods. The drawing which is reproduced here is by Mr. John Allen, and I would express my indebtedness to him for the trouble and care he has bestowed upon it. The drawing is the size of life; the specimen being about 35 c.m. in length excluding the tuft of roots.

Each complete specimen of *Sarcodes* consists of a flowering spike with fleshy scales and a considerable tuft of roots. The whole of the epigeal parts are coloured a brilliant crimson, due to the presence in the superficial cells of the plant of a soluble, red colouring-matter, allied probably to the tannin series. It is, like its allies, entirely destitute of chlorophyll.

[1] O. Drude, Die Biologie von *Monotropa Hypopitys*, L., und *Neottia Nidus avis*, L. Göttingen, 1873.

[2] Fr. Kamienski, Les organes végétatifs du *Monotropa Hypopitys*, L. Mém. Soc. Nat. d. Sc. Nat. et Math. d. Cherbourg, t. xxiv, 1882.

[3] John Torrey, Plantae Frémontianae, p. 17 and Pl. x, Smithsonian Contributions to Knowledge.

[4] G. A. Chatin, Anat. Comp. d. Végétaux (Plantes parasites), tab. lv.

The plant is vegetatively reproduced, I apprehend, by buds from the roots in the same manner as *Monotropa*; new flowering shoots arising in this way each spring. Besides this, the number of seeds formed is very great.

The following is Torrey's original description of the plant:—

'SARCODES, *Torr.* in Plantae Frémontianae, p. 17, tab. x.

'*Calyx* quinquesepalus; sepalis concavis, basi vix gibbosis. *Corolla* campanulata, persistens, quinquelobata; lobis ovatis, erectis. *Stamina* 10, hypogyna; filamenta subulato-filiformia; antherae oblongae, biloculares, didymae, fere ad basim introrsum affixae; loculis sacculaeformibus, apice oblique truncatis, foramine amplo hiantibus. *Ovarium* hemisphaericum, quinquelobatum, quinqueloculare; loculis multiovulatis. *Ovula* horizontalia, anatropa. *Stylus* elongato-columnaris; *stigma* capitatum, subquinquelobum. *Discus* nullus. *Capsula* depresso-globosa, subquinqueloba, quinquelocularis. *Semina* numerosissima, ovata, aptera; testa reticulata. *Embryo* in basi albuminis, minutissimus, indivisus.—Herba *Californica, carnosa, rubra; caule simplici, squamis carnosis vestito, in spicam conferte bracteatam desinens; floribus pedicellatis.*

'S. *sanguinea*, Torr. l.c. (*sp. unica*). Hab. Sacramento Valley, California. Colonel Frémont.'

The specimens on which this paper is based were collected by Messrs. Godman and Elwes near San Bernardino in the San Bernardino range, some 250 miles south of the Sacramento Valley where the specimens described by Torrey were taken. This then considerably extends the range of the plant.

The structure of the vegetative and floral organs of *Sarcodes* will now be considered in detail.

THE VEGETATIVE ORGANS.

The vegetative organs of *Sarcodes* agree in general, both in external conformation as well as in histological differentiation, with those of a large number of other saprophytic phanerogams destitute of chlorophyll. The organs in general are fleshy; the leaves are reduced to scaly imbri-

cating structures; the much-branched roots are associated with an investing fungal mycelium. All the shoots which appear above the soil are flowering shoots; purely vegetative shoots do not occur. As in many other saprophytes, the vegetative organs are brightly coloured and the number of seeds produced is very great. The embryos also are very small, and the amount of food-material (endosperm) accompanying them meagre.

Histologically, the tissues are not so well differentiated as in plants with a normal metabolism.

The vascular bundles are accompanied by large quantities of parenchyma; the sieve-tubes are small and not very numerous; the vessels and tracheides of the wood narrow, and often only imperfectly lignified. Stomata are entirely wanting, and intercellular spaces infrequent. These points in histological differentiation are associated with an absence of carbonic acid assimilation and a reduced transpiration-current.

The whole of the succulent pith and cortex of the stem consists of very thin-walled parenchyma-cells, crowded with starch-granules during early stages of development; it serves as a store of food-material to be used in the production of flowers and ripening of seed.

The more detailed account of the various parts is treated in the following order:—(1) Roots, (2) Stem, (3) Leaves, (4) Morphology of Flower.

1. *The Roots.*—The structure of these is of great interest in view of the general habit of this plant and of its dependence on organic matter in the substratum for much of its nutriment. The roots are attached in great quantities to the bases of the flowering shoots and form large and intricately woven masses of 'coralline' appearance[1]. The specimen of *Sarcodes* on which this account is based had lost all but a relatively small portion of its roots before it reached my hands. It will be noted that the tuft represented in the portrait (Fig. 1) is only a small portion of the total cluster of roots. These roots

[1] I understand that the mass of roots attached to each specimen is often so large as to equal in bulk the whole remaining epigeal part of the plant.

present very constant (if exceptional) characters which agree with those belonging to herbarium specimens collected at various periods. With a little care the different root-axes can be dissected away from one another. Fig. 41 shows a fairly young portion of one axis drawn under the simple microscope. It bears numerous short branches (rootlets) arranged in four or five longitudinal rows, thus differing from *Monotropa*, which bears its rootlets in two or three rows. There secondary roots, in time, elongate and bear, in the same way, numerous roots of the third degree. By this continued branching the characteristic, dense, interwoven mass is produced. The lateral roots (of whatever degree) are not produced at right-angles on the axis from which they arise, but always slope forwards; the axis of a lateral root making an angle of about 45° with the region of its mother root in front of its insertion. These lateral roots, while still very young and not exceeding three or four millimetres in length, are already beset with little tubercles. These tubercles represent the origin of young rootlets.

Everywhere the surface of the roots is of a deep brown colour, and under a strong lens it shows a certain roughness of texture not found on the roots of ordinary plants. The roughness in question is due to the fact that the roots of *Sarcodes* are everywhere invested in a close-fitting sheath of fungal mycelium. Further examination shows that the roots here, as in *Monotropa*, display in a marked degree the phenomenon of *Mycorhiza*.

First as to the more intimate structure of these roots. They are usually relatively thick and fleshy. A transverse section reveals a central vascular cylinder surrounded by a broad parenchymatous cortex. If the diameter of any root be 2 mm., that of the vascular cylinder will not exceed ·5 mm. The xylems, usually five in number, are arranged in a ring, alternating with softer regions, the phloems, in the manner characteristic of roots. In the younger regions there is a central pith, gradually however becoming lignified and binding the individual xylems into one mass. The xylem consists of

tracheides, for the most part with scalariform thickenings; there are a few, in the protoxylems, with spirals. The endodermis is difficult to define, and I doubt if such a layer can really be distinguished here. The succulent cortex is well stocked with starch, throughout, from bundle-cylinder to epidermis. The epidermis does not form a continuous mantle, with cells fitting everywhere closely edge to edge, but consists of a layer of tube-like cells—the long axis of each cell being at right-angles to the surface of the root (*e*, Fig. 44). Each epidermal cell is laterally not in contact with its neighbours, but is isolated by the ingrowth of hyphae from the investing mycelial sheath above mentioned. The epidermal cells at their first origin are in contact, but early in their history the hyphae penetrate between them, and closely invest each epidermal cell on every side except its base (cf. Figs. 44 and 45). In Fig. 44 the epidermal cells are seen in most cases in section; two only (*a* and *b*) show a side-wall lying in the plane of section with the hyphae creeping over them. The nuclei of the epidermal cells are rod-like, or even dumb-bell shaped, and lie in the basal third of each cell. They are placed for the most part at right-angles to the long axes of the epidermal cells (Fig. 44, *n*). Starch occurs in the epidermis very rarely, though in quantities in the subjacent cortex. Outside is the layer of fungal mycelium constituting the mycorhiza. This layer is particularly well exhibited in *Sarcodes*, where it attains a thickness of ·2–·25 mm. The inner part, abutting on and penetrating between the epidermal cells, forms a very compact pseudo-parenchyma. In the outer layers of this denser stratum are embedded layers of flattened, dead cells, coloured deep brown with tannin. These layers, as will be shown below, are the remains of the root-cap. In an ordinary plant, in the absence of an investing fungal layer, the outer layers of cells of the root-cap fall away and the cap is renewed from within by a generating layer. Here, however, from the manner in which the hyphae are interwoven around them, this does not happen. Indeed, on the oldest roots, this same sheath—the survival of the root-cap—remains still enclosed

in the hyphal zone. Proceeding outwards, the texture of the mycelium becomes looser, and it no longer forms such a dense pseudo-parenchyma. The individual, septate, tubules (hyphae) are distinguishable, and at the periphery their ends turn radially outwards, terminating blindly in a manner resembling root-hairs.

It will be well now to describe the relation of the parts at the root-apex before treating of the phenomenon of mycorhiza in greater detail. Fig. 43 represents a longitudinal median section of a root-apex of *Sarcodes*. Right and left, low down, the columnar epidermal layer is seen (*ep*). It may be easily followed right up to the apex, where it is covered in by the several layers of the root-cap. Indeed the root-cap arises in common with the epidermis, being formed from it by repeated tangential divisions. The inmost, and youngest, layer of the cap (*rc'*) is shown as having arisen quite recently in this way. Each layer of the root-cap in turn has originated in this manner, as an examination of Fig. 43 will show. Each extends a little further down the root than the one inside it, the fifth or sixth layer forming the outermost functional layer of the root-cap. The older layers have separated some little way from these by the ingrowth of the mycelium, and are still held there as described. In Fig. 43 they are not represented. The dermato-calyptrogenic layer is quite distinct from the initial group of periblem and plerome cells. These latter arise in common, and it is only a little way backwards that the distinction between them becomes manifest—the cells of the plerome undergoing longitudinal division more frequently than those of the periblem. Such a grouping of the cells at the root-apex is likewise found in *Monotropa*. The cap, however, in this latter genus is exceedingly thin, being only one or two cell-layers thick [1].

The apex of the root is everywhere enveloped in the mycelium. In this point *Sarcodes* differs from *Monotropa*. In *Monotropa* the extreme tip is quite bare, and the fungus is

[1] Cf. Kamienski, l. c., Pl. I. Fig. 5: also p. 11.

entirely post-apical. This distribution, stated by various authors, I have been able to confirm. Embedded in the hyphae are found the old layers of the cap that have become detached (Fig. 42), and a little distance behind, where the epidermis is immediately presented to the mycelium (the outmost *adherent* layer of the cap ceasing here), the ingrowing tubules of the fungus may be seen penetrating between the epidermal cells in the manner shown in Fig. 44.

These filaments never *enter* the epidermal cells, nor do they penetrate to a lower level than the base of the epidermis. The same arrangement is found in *Monotropa*. As the apex grows forward the outer layers of the cap continually break away from the underlying ones, but the mycelial layer prevents their falling away from the organ, hence they remain as strata—or as a series of hollow shells—kept in place, to even a great distance from the apex, by the hyphal layer. The mycelium must also keep pace in its growth with the elongating tissues of the root-apex; otherwise a rupture would occur.

The mode of branching of the roots of *Sarcodes* is exceptional and of considerable interest. A glance at Fig. 41 shows lateral roots arising remarkably near the apex. When the matter is investigated more closely it appears that *all lateral roots in* Sarcodes *have an exogenous origin*. Fig. 42 shows an early stage in the development of a lateral root, as seen in longitudinal section. The first indication of this event is a slight bulging of the periblem, accompanied by a radial division of the overlying dermatogen. Tangential divisions then arise in the dermatogen and the first layer of the root-cap of a new lateral root is formed (*rc'*, Fig. 42). The lateral root arises so near the apex that it is enveloped in the root-cap of the mother-root. In the undifferentiated tissue a plerome is differentiated, becoming continuous with that of the primary root. This takes place before the young rootlet commences to grow, appreciably, in length (Fig. 42). I have examined the insertion of a great number of lateral roots of all ages, but in no case does any exception occur to the rule

that, in *Sarcodes*, all lateral roots are formed exogenously and not from any internal pericycle as happens in ordinary cases.

In *Monotropa*, on the other hand, the roots branch always normally, that is, endogenously. This was shown by Drude[1] and by Kamienski[2], and I have found it to be the case in all specimens examined. The only other genus of Monotropeae, the roots of which have been available for examination, is *Pterospora*. Here, not only is there a well-marked mycorhiza, but the root-branching is *exogenous* and agrees with *Sarcodes*. That these root-like organs in *Sarcodes* and *Pterospora* are true roots is not, I think, to be questioned. They possess well-marked root-caps, their bundles are radially arranged, and there is a total absence on them of scale-leaves of any kind.

The exogenous branching of the roots, occurring in *Sarcodes* and *Pterospora*, may be regarded as a special adaptation, in these plants, that has been perpetuated as being a useful variation. By an exogenous method of root-branching the formation of a wound, which must always occur in endogenous branching, is avoided, and the inner tissues of the plant will not be so liable to the entry of the fungus forming the mycorhiza. In the case of endogenous branching the wounds formed in the cortex, by the penetration of the lateral roots, must be points of weakness should there be any tendency on the part of the fungus to make an entrance. It must be admitted that in *Monotropa*, where lateral roots arise endogenously, no such behaviour of the fungal hyphae has been observed. However, before discarding the view above put forward it must be remembered that at present really very little is known of the nature of these mycorhiza-fungi, and whether the conditions that obtain in one case hold good for another. An alternative, and perhaps simpler, explanation of the phenomenon may be suggested by the general reduction of the vegetative organs, as a whole, in these saprophytic plants. The organs of plants which obtain most of their food in the form of complex organic substances show less histo-

[1] Drude, l. c., p. 43, and Pl. III. Fig. 15.
[2] Kamienski, l. c., p. 18, and Pl. I. Fig. 8.

logical differentiation than where a normal metabolism exists; and processes of a complex nature—as for instance the endogenous development of lateral roots—may gradually, in the general degradation, give place to simpler methods. My own view, however, is that here the exogenous root-branching is an advantageous variation that has been perpetuated.

As regards the relation of the roots of *Sarcodes* to the substratum:—from notes kindly communicated by Mr. Elwes no direct connection would appear to exist between them and the pine-roots among which *Sarcodes* grows. The plant vegetates amongst decaying portions of the pines, leaves and the like, and possesses nothing of the nature of haustoria or parasitic attachments. No doubt *Sarcodes* resembles *Monotropa* in this respect, and, as in this case, although the roots of the saprophyte come into very intimate relation with the roots of other plants, still they are never organically united [1]. I have been at some pains to ascertain whether *Monotropa* roots ever form haustoria, and for this purpose have examined many specimens of *M. glabra* from beech- and of *M. hirsuta* from pine-woods, without meeting with a single case to support the view of parasitism. Not infrequently I found the

[1] In view of the prominent position now held among botanists by the Mycorhiza question, it may not be without interest to call attention here to the observations of certain British naturalists of a past generation, more especially as they have been quite lost sight of in the recent discussion of the matter. In the years 1841–2 a lively discussion was running in the pages of the now defunct 'Phytologist.' Ed. Lees (p. 97) speaks of 'a hirsuture that appears like a byssoid fungus' on the roots of *Monotropa*. This 'hirsuture' he considered to be a portion of the *Monotropa* plant, which he regarded as a parasite. Wm. Wilson (l. c., p. 148) failed to discover any parasitic attachments, and considered the 'byssoid growth' as certainly no part of the plant. A little later (l. c., p. 297) we find Ed. Newman speaking of the 'byssoid growth' as an essential part of the plant, thus agreeing with Lees in that point. He differs from Lees, however, in denying its parasitic habit. Finally, T. G. Rylands, in a detailed paper (l. c., p. 341), ends the discussion. His paper is illustrated with a number of woodcuts. The 'byssoid substance,' he says, 'is really fungoid, and performs no essential function in the economy of the *Monotropa*.' He detected three types of Fungi—*Sepedonium*, *Epiphagos*, and *Zygodesmos*, the last characterised by buckle (geniculated) hyphae. Hence it appears that although the anatomical relations of the *Monotropa* roots were long ago familiar to naturalists, the view as to the symbiotic nature of mycorhiza is essentially modern.

beech-roots (generally dead) wrapped round with a weft of the same mycelium that formed the mycorhiza on the *Monotropa*, but never any haustoria. Drude[1], who though he had found such connections, and figured them, has not been confirmed by Kamienski[2]. My own examination confirms Kamienski on this point. *Sarcodes* may safely I think be regarded, like *Monotropa*, as a saprophyte or humus-plant[3].

2. *The Stem.*—This is everywhere hidden from view; below by the imbricating scale-leaves, above by the bracts and flowers and by the flower-buds. It is very thick and succulent; its diameter at different heights in the specimen drawn in Fig. 1 was 2·5 cm. at the base; 4·5 cm. at a distance of 10 cm. from the base; then gradually tapering off towards the apex. The thickest portion corresponds to the thickest part of the 'bulb.' The bulk of the stem is built up of a succulent parenchyma in which is disposed a ring of vascular bundles, which is somewhat nearer to the periphery than to the centre of the stem. In this specimen, in which the seed was not yet ripe, the parenchyma was everywhere well-stocked with starch grains. In their chemical and physical properties these grains are indistinguishable from those in the tissues of ordinary green plants. This I mention as Drude[4] finds the 'starch grains' of *Monotropa* differing in certain respects from normal starch, and gives to the substance of which they are composed the name of Monotropin. The bulk of the starch in the stem of *Sarcodes* is employed in the ripening of the seeds. With the ripening of the seed the shoot dies down, new shoots being formed each year by direct budding from the roots.

Any transverse section through the stem in the lower

[1] Drude, l. c., p. 45, and Pl. IV. Fig. 16. Drude only found them exceptionally.

[2] Kamienski, l. c., p. 30.

[3] An interesting observation is communicated by Mr. Wolley Dod to the Gardeners' Chronicle (August 17th, 1889, p. 195). He found that *Monotropa* which flourishes amongst the roots of Willows in the neighbourhood of Southport was often growing in rings, after the manner of a 'fairy ring.' He suggests that this phenomenon is perhaps due to the same cause.

[4] loc. cit., p. 49.

'bulbous' portion of the plant shows an irregular outline, due to the bases of the closely imbricating scales (Fig. 46). The shield-like sections of these latter are not quite symmetrical (Fig. 46, *lb*), owing to the rather oblique insertion of these scales.

As regards the distribution of the vascular bundles in the stem: the bundles form an undulating ring around the succulent pith. Between this ring and the periphery of the stem are seen the bundles which pass off to supply the leaves and, where they occur, to the flowers. Fig. 46 is a transverse section through the lower portion of the stem. The bundles to the leaves pass out in groups of two, these again spreading in a tangential direction when they reach the leaf. Higher up, in the region of the inflorescence (Fig. 47), there is, on the inside of each pair of bundles passing to the leaves, a small group which supplies the axillary flower-stalk. The distinction between these two groups of bundles is well shown in Fig. 48 (*fb* and *lb*). The orientation of the bundles is that characteristic of Dicotyledons, an inner xylem and outer phloem arranged collaterally (Fig. 48). The bundles undergo no secondary increase in thickness. The xylem is small in quantity in comparison with the total bulk of the plant; a reduction doubtless correlated with the small transpiration-current. The ring of bundles is traversed by relatively broad medullary rays at frequent intervals. The elements of the xylem are scalariform vessels and (in the protoxylems) narrow spiral vessels.

Corresponding to each xylem-group is a phloem-group (Fig. 49). The phloem is built up entirely of soft elements. These consist of narrow sieve-tubes with slightly oblique sieve-plates, companion-cells, and a large amount of small-celled phloem-parenchyma. Thin callus-plates are present on the plates of some of the more peripheral sieve-tubes. Neither the sieve-tubes nor their companion-cells show any special peculiarity.

3. *The Leaves* show a gradual transition in form, from the small scales at the base, to the thick, fleshy ones covering the

greater part of the vegetative portion of the shoot. These again pass over into the linear bracts. This is illustrated in Fig. 50, *a–e*, each drawing being of the natural size. The leaves and bracts are fringed with stalked glands. The whole outer face, especially in the case of the bracts, is pubescent. Fig. 51 shows the margin of a bract, under the simple microscope, with the glands; whilst in Fig. 52 a longitudinal section of a single gland is given. The structure of the scales calls for no special comment. They consist of a number of layers of thin-walled parenchymatous cells traversed in the median plane by a number of reduced, collateral, vascular bundles. The limiting epidermis is cuticularised except at the glands. No stomata are present, and the intercellular system is not well-marked.

4. *Morphology of the Flower.*—Each individual shoot, as in *Monotropa*, terminates in an inflorescence, here crowded and bearing a large number of flowers. The inflorescence is built on the indefinite type (racemose), and *Sarcodes* would appear to be unique amongst Monotropeae in this respect. *Monotropa* and the others have the leading flower of the inflorescence terminating the axis. The proportion borne by the inflorescence to the rest of the plant is sufficiently shown in the portrait of the plant (Fig. 1). The closely imbricating scales of the 'bulbous' portion pass over gradually into others, less fleshy, more loosely arranged, and somewhat narrower and longer (cf. Fig. 50, *a*, *b*, *c*, *d*, and *e*). These may be spoken of as the *bracts*; each subtends a single flower. The lower flowers have fairly long pedicels, exceeding the length of the flower several times; those above are gradually shorter. At the time when the shoot is elongating, and the spike of flowers being pressed through, and elevated above, the surface of the ground, each flower-bud is ensheathed and protected by its subtending bract. The bracts themselves are hollowed out in a boat-like manner, as shown in Fig. 4. Later, when the flowers are about to expand, the bracts curve backwards and the flowers are exposed. The bracts persist until the ripening of the fruit. Like the scaly,

fleshy leaves, they are fringed with a series of short processes of a glandular nature, and the whole outer face is covered with small glands. The head-cells of these glands possess a very granular protoplasm, but with the nature of the secretion I am unacquainted. It is not improbable that they serve to ward off the visits of 'unbidden guests,' creeping insects abounding in the humous mould in which *Sarcodes* grows.

Throughout, I have found the flowers to possess 5-merous symmetry with superior ovary, and all floral members entirely hypogynous. There are no bracteoles, and the sepals form a very definite whorl. The individual sepals are entirely free from one another down to the base. They are bright crimson in colour, and are covered externally with small glands resembling those of the bracts. The sepals are inserted on the two-fifths arrangement, and, like the petals, are persistent.

The corolla, unlike the calyx, is entirely smooth, almost waxen in appearance. It is sympetalous, its members being united to about half-way up. It equals the calyx in length, but its lobes are slightly curved outwards at the tip and project between the tips of the sepals (Fig. 3). The aestivation of the corolla in the bud is always contorted, as shown in the floral diagram (Fig. 23).

Passing on to the stamens. These are ten in number, and stand, in the mature flower, and in the youngest flower-buds available, in apparently one whorl. They are little more than half the length of the corolla, and the anthers are held vertically in a ring, just below the stigma. The filaments are subulate and, at the base, slightly expanded, becoming connate. These relations are shown in Fig. 3. The lower thirds of the filaments are pressed closely against the ovary, and between them project the ten lobes of the ovary, the stamens lying in the grooves between these lobes. The anthers are basifixed, and the two halves are parallel. Each anther-half possesses, in the usual manner, two loculi. Dehiscence takes place by two oval pores at the top, and towards the *outside*, of

the anther: dehiscence is thus extrorse. The method of dehiscence is of some interest. The two oval pores situate on the dorsal (outer) side of the anther are shown in Fig. 5. The pores lead, *immediately* only, into the two loculi which are directed *away from* the ovary (Fig. 6, A). During development (after the maturing of the pollen) the walls separating the anterior and posterior loculi of each anther-half break down, so that pollen formed in the loculi *towards* the ovary can likewise escape by these pores. Fig. 6, A, B, and C, represent transverse sections of the anther taken at heights corresponding to A, B, and C in Fig. 5. A alone traverses the region of dehiscence and shows the openings leading into the dorsal cavities. The wall that breaks down in development is indicated by dotted lines.

Dehiscence is not effected by any 'fibrous layer,' but the epidermis in the region where rupture occurs is strongly developed and columnar; dehiscence is caused by the separation of these cells along a certain line as they dry. This is shown in Fig. 7, which represents as it were the left-hand bottom corner of such a section as Fig. 6, A. The dorsal loculus (*d l*) very small, then the broken down partition (*p*), and the much larger ventral loculus (*v l*). Noteworthy is the occurrence of a strand of fibrous and lignified cells (*f* in Fig. 7) immediately below the epidermis. This strand runs down the outer lip of the pore. A dotted line around the left pore (Fig. 5) marks the course of the strand in question. I attribute a strengthening function to this hardened tissue; perhaps it prevents rupture of the wall of the anther directly into the ventral loculus (as at such a point as *x*). Fig. 8 is a transverse section across a young anther, just after the partitions have broken down, but before any opening to the outside has been made.

The pollen is powdery and simple, and not massed together, as in many Monotropeae. The grains are spherical, with outer and inner walls (Figs. 13, 14, and 15). The two nuclei of each grain are very easily seen on staining. One is spherical (the vegetative nucleus), the other spindle-shaped (the generative nucleus) and curved in a crescentic manner (Figs. 13 and

14). At an earlier stage, at the time when the tapetal layer is breaking down, and immediately after the division of the pollen-mother-cells, the division into two cells in each pollen-grain is very clearly shown (Figs. 10, 11, and 12). These cells are unequal; the larger one contains a larger nucleus, often with two nucleoli at this time; the other, small and bi-convex, a much smaller nucleus. It is the larger nucleus that is afterwards spindle-shaped and constitutes the generative nucleus of the pollen-grain. There is an absolute separation of the protoplasmic bodies of the two cells within the pollen-grain; later however they fuse. Occasionally the division is found to be into equal parts (Fig. 15). The division of the mother-cells into pollen-grains takes place in the ordinary, dicotyledonous manner, the pollen-grains lying, as tetrads, in the mother-cells (Fig. 9).

A great number of pollen-grains is present on mature stigmas, and the pollen-tubes may be very readily dissected out from the style and ovary. In these tubes very large plugs are developed cutting off the lumen of the younger portion from the lumen of the older. These plugs arise first as annular cushions on the inside of the wall whereby the lumen is constricted. This goes on until the cavity at that point is obliterated (Fig. 16, *a* and *b*). Deposition of substance often continues till the pollen-tube is plugged for a length of ·25 mm. Often the thickening is very irregular and recalls the callus-depositions in the trumpet-hyphae of certain Laminarieae (cf. Fig. 16, *c*, *d*, and *e*). No layers of stratification are demonstrable even with the highest powers of the microscope, nor after using re-agents.

The Ovary has a very broad attachment to the receptacle. Its horizontal diameter exceeds by more than one-third its vertical. It is produced upwards into an erect style, bearing a 5-lobed stigma. The whole height of the gynaeceum is about two-thirds that of the corolla. Externally the ovary is prominently 10-lobed, each lobe projecting between two stamens (Fig. 3). Each lobe is continued down into a nectar-secreting region (*n*, Figs. 3 and 17), and in longitudinal section

it is seen that the wall of the ovary is thickened at points corresponding to the nectariferous areas. The arrangement of the nectaries in the different genera of Monotropeae is a matter of much interest. Thus, in *Monotropa glabra* (Fig. 22), each lobe of the ovary is produced downwards into a small appendix, the nectary *n*. These appendices curve in pairs, embracing the antipetalous stamens, and drop their nectar into the gibbosities of the petals. This is shown in Fig. 22, the petalline stamens ($p\,s$) in each case being thus embraced. The petal (p) shown in the figure receives the nectar from glands surrounding the stamen $p\,s^2$. The other petals have been removed, but their scars do not show since their insertion is so close up under the stamens: *s s* are the basal portions of the sepals which stand in a very loose spiral. Other genera, likewise, afford most interesting details, but a special account of these structures in other members of the order is deferred to a future paper.

The ovary itself is 5-carpellary, each carpel being bilobed (cf. Fig. 21, *H*, a transverse section taken midway between the base of the ovary and the insertion of the style). The figure shows the five septa and the enormously developed axis, with a bilobed placenta projecting into each 'cell' of the ovary. The lobing of the ovary wall corresponds entirely to the lobing of the placentas. In this type the transition, from parietal to axile placentation, is well shown, and is illustrated in the series of transverse sections, Fig. 21, *A–H*. *A* is through the stigma, and the inwardly projecting lobes appear lower down as the ovarian dissepiments; *B* is across the style, and shows the 'style-canal'; *C* is through the insertion of the style on the top of the ovary, and shows the enlarging lobes. In 21 *D* the region where ovules are borne has been reached. In *E* the placentas are much enlarged and the central cavity correspondingly diminished; in *F* this is carried till finally in *G* there is absolute fusion of the placentas, and, in the greater part of the ovary, the lines of fusion are indicated by the median groove in each of the five placentas (Fig. 21, *H*). This series of sections shows sufficiently clearly that in the

same ovary the placentation is parietal above, axile below. Further remarks on the nature of the placentation and on its possible origin are deferred till further investigations on the floral morphology of the Monotropeae are completed. It is exceedingly difficult to argue from one particular case whether axile is derivable from parietal placentation, or whether the reverse is the case.

That the style-canal gives access to each ovarian chamber is easily to be inferred from the series of transverse sections described. In Fig. 17 is drawn a dissection of an ovary showing more exactly this communication. On the left the section has passed exactly in the median plane of a loculus, and the continuity of the ovarian chamber and the style-canal is seen to be direct. On the right, the section has passed through *one side* of the loculus, and the direct continuity does not appear. However, the dark shading *ch'* indicates the chink leading into the loculus, and a bristle can be easily passed through it and out into the ovarian cavity. In the same way the chink ch^2 leads into that chamber of the ovary immediately behind. The lighter regions, between the chinks (Fig. 17), indicate ridges running longitudinally down the style (the same as are figured in Fig. 21, *b* and *c*). The ovules are small and exceedingly numerous, as in Orchids.

The calyx and corolla are persistent till the ripening of the fruit. The wall of the ovary becomes hard and brittle, but dehiscence is not effected by a separation of the ovary into valves, as happens in *Monotropa*, and in some other genera of the order; it is *circumscissile*. Dehiscence is effected by the formation of a circular split, around the base of the style, at a little distance (1–1½ mm.) from it. It is by this that the seeds escape, since the wall of the fruit does not separate into valves. The circular chink is shown in the drawing of the dissected fruit (Fig. 20, *d*). The bi-lobed placentas in two of the chambers of the ovary are exposed in the dissection.

The method of dehiscence here obtaining illustrates how, by a special adaptation, advantage is taken by a plant of a structure common to it and its allies, but which has not been

made use of by the allied genera. At the time of flowering, there is around the base of the style a ring-like depression, or invagination, of the epidermis. This is seen in the longitudinal sections of the ovary represented in Figs. 17 and 18; also in the transverse section, Fig. 21, *C*, taken at the insertion of the style. In a more highly magnified longitudinal section (Fig. 19) the nature of the depression is seen. It penetrates three quarters of the way through the ovary wall, and only a narrow zone of tissue separates it from the cavity of the ovary. It is the small cells (*x*, Fig. 19) of this region that, breaking down as the fruit ripens, bring about the peculiar dehiscence (circumscissile) described above. In *Monotropa* a circular depression occurs in the same position, but its depth is only one-third of that in *Sarcodes*, and it does not lend itself to this method of dehiscence. Similarly, in some other genera of Monotropeae.

In old specimens of *Sarcodes*, when many of the fruits are already in seed, small flowers appear in the axils of the fleshy leaves, below the general inflorescence. These, in ordinary flowering specimens as that figured, are still minute buds, 1 mm. in length, embedded in the fleshy bases of the scale.

Development of the Ovules. — The ovules are very numerous, and their development can be easily followed. Each arises on the young placenta as a small upgrowth of tissue, by the formation of tangential divisions in the layer immediately below the epidermis. At an early period the terminal cell of the hypodermal tissue of the young ovule is marked out by its relatively large size (Figs. 24 and 25, *a*), and as the terminal portion of the ovule (nucellus) begins to curve over, it becomes very prominent. At the same time, the commencement of the single coat of the ovule arises (Fig. 25, *int*). The large terminal cell is the *archesporium*, and it undergoes a number of divisions, prior to the formation of the embryo-sac. These are shown in Figs. 26–30. There is, cut off from the apical end of the archesporium, first one and then a second 'cap-cell' (*cc* in Figs.); this number is not exceeded. The large, third cell of the row, so formed, is the embryo-sac. In succeeding stages the cap-cells gradually dwindle as the

embryo-sac elongates. The nucleus of the embryo-sac divides (Fig. 30), and the daughter-nuclei travel to the two ends; a large vacuole arising in the protoplasm between them (Figs. 31 and 32). Each nucleus divides a second time (Fig. 33), and then once again. Two of the four nuclei, at the micropylar end, become the nuclei of the two synergidae, a third that of the egg-cell (oosphere), whilst the fourth moves downwards and fuses with a similar, ascending one from the lower group, constituting the 'definitive nucleus of the embryo-sac' (Figs. 34 and 35). The three nuclei, remaining at the basal (chalazal) end of the embryo-sac, are the nuclei of the antipodal cells. They become invested with cell-membranes, and play no further part (Figs. 34, 35, and 38). The embryo-sac, as represented in Fig. 34, is ready for fertilization. The definitive nucleus is suspended by delicate filaments of protoplasm. After fertilization, the synergidae disappear and divisions arise in the egg-cell. Soon, a rudimentary embryo is formed, consisting of a short suspensor of three cells and an enlarged embryonic cell, in which the formation of one or two anticlinal walls may be traced (Figs. 36, 37, 38, and 39). Simultaneously with the segmentation of the egg-cell, the definitive nucleus divides. Each nuclear division is accompanied by the formation of a delicate transverse wall (Figs. 36, 37, and 39). The cells so arising constitute the endosperm. Even in the ripe seed the endosperm is relatively scanty. The seeds formed are extremely numerous, small and light, a condition not infrequently met with among plants with saprophytic or parasitic habit. They are destitute of any wing. I was unable to study the later stages in the development of the seed, owing to lack of material sufficiently advanced, but very few more divisions arise either in the embryo or in the endosperm. The history of this development agrees closely with that given by Strasburger[1] and Koch[2], for the allied *Monotropa*.

In this paper I have confined myself to the description of

[1] E. Strasburger, Ueb. Befruchtung und Zelltheilung. 1878.

[2] Koch, Entwickl. d. S. in Pringsheim's Jahrb. f. wiss. Bot. xiii.

the more salient points presented by *Sarcodes*, and do not propose to enter here into any discussion as to its position in the order Monotropeae and affinities. This can be done with more profit in a paper dealing with the morphology of all the members of the group, as to which at present our knowledge is imperfect. That the group as a whole will repay investigation I have little doubt. Amongst other matters of interest would be the determination of how far the points of distinction of its several members are adaptive. That many of them are so is, I think, probable.

JODRELL LABORATORY, KEW.

EXPLANATION OF FIGURES IN PLATES XVII, XVIII, XIX, XX, XXI.

Illustrating Mr. F. W. Oliver's paper on *Sarcodes sanguinea.*

Fig. 1. Life-size portrait of the plant at the time of flowering in natural colours. Only a portion of the roots of the plant is shown. Drawn by Mr. John Allen.

Fig. 2. A single flower with two sepals removed. *k*, calyx; *c*, corolla. Natural size.

Fig. 3. View of the interior of a flower after removal of part of corolla, showing the stamens and anthers with porous dehiscence, the nectaries, ovary and stigma. *k*, calyx; *c*, corolla; *st*, stamen; *n*, nectary. (2/1.)

Fig. 4. A single flower-bud with its subtending bract attached. To show the curving of the bract round the bud. *br*, bract. Natural size.

Fig. 5. View of an anther seen from the dorsal (outer) side. Right and left are the two halves of the anther adnate to the filament. The letters A, B, C, indicate the heights at which the corresponding sections in Fig. 6 were made. *cn*, connective; *f*, shows position of sclerized layer at margin of pore; *fl*, filament; *p*, pore. (12/1.)

Fig. 6, A, B, C. Transverse sections of anther cut at heights indicated in Fig. 5. The dotted lines indicate the partitions which break down in development. *v*, ventral side; *d*, dorsal side. (12/1.)

Fig. 7. Transverse section of part of an anther more highly magnified to show the sclerized strand running in the wall just to the outside of the dorsal pollen-sac. *cn*, connective; *d l*, dorsal pollen-sac; *f*, sclerized strand; *p*, remains of broken-down partition; *v l*, ventral pollen-sac. (120/1.)

Fig. 8. Transverse section of a younger anther, showing first rupture of partition between dorsal and ventral pollen-sacs. *d*, dorsal; *v*, ventral side. (18/1.)

Fig. 9. A pollen mother-cell containing a tetrad of pollen-grains, each as yet with a single nucleus. The fourth grain not shown.

Figs. 10, 11, and 12. Single pollen-grains after division of contents into a larger and a smaller cell.

Figs. 13 and 14. Somewhat later stage in development of pollen. The cell-protoplasm no longer shows division into two masses. The two nuclei show characteristic differentiation, one being spindle-shaped, the other globular.

Fig. 15. Showing division of contents of pollen-grain into equal portions. Not frequently met with.

Fig. 16, *a*, *b*, *c*, *d*, *e*. Callus-like thickenings in the pollen-tubes. (400/1.)

Fig. 17. Longitudinal section through the ovary, showing the fleshy axile placenta, the ovules and the style-canal, and the method of communication between it and the various chambers of the ovary. *c*, corolla; *ch*, chinks leading from style-canal into ovarian chambers; *k*, calyx; *n*, nectary; *p*, placenta with ovules; *r*, annular invagination surrounding base of style, by the agency of which circumscissile dehiscence is afterwards effected; *s c*, style-canal; *st*, insertion of stamen. (Enlarged several times.)

Fig. 18. Longitudinal section of the upper part of the ovary, showing the ring-like depression around the base of the style. *ov*, ovarian cavity; *r*, annular depression; *s c*, style-canal. (8/1.)

Fig. 19. Much enlarged view, showing the annular depression in a longitudinal section similar to that represented in Fig. 18, and its relation to the cavity of the ovary. *b s*, base of style; *r*, annular depression; *ov*, cavity of ovary; *ow*, wall of ovary; *x*, cells which in dehiscence break down. (60/1.)

Fig. 20. A ripe fruit laid open so as to show the bi-lobed placentas covered with very numerous minute seeds, the circumscissile method of dehiscence, and the rupture of the dissepiments; *d*, region of dehiscence.

Fig. 21, *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H*. A series of diagrams representing the placentas and their relation to one another as shown in a number of transverse sections of the stigma, style and ovary. *A* is through the stigma; *B* through the style, with central cavity the style-canal; *C* is through the insertion of the style on the ovary, and so on to *H*, which is cut about half-way down the ovary. It is seen that in the upper part of the ovary the placentas, which are directly continuous with the ridges projecting into the cavity of the style, are free from one another; that fusion occurs lower down (*G*), and that in the whole of the lower part of the ovary they are completely consolidated (*H*). (Enlarged.)

Fig. 22. Flower of *Monotropa glabra* dissected so as to show the nectaries at the base of the ovary. *p*, a petal remaining *in situ*; *s s*, insertion of sepals; *n n*, nectaries, each occurring as an appendix at the base of a carpellary lobe; *p s*, petaline stamens. (Enlarged.)

Fig. 23. Floral diagram of *Sarcodes sanguinea*.

Figs. 24–40. Series of drawings illustrating the development of the ovule and of the embryo-sac up to the time of formation of the embryo. *a*, archesporium; *a e s*, accessory embryo-sac; *ant*, antipodal cells; *c c*, cap-cells; *d n*, definitive nucleus of embryo-sac; *emb*, embryo; *end*, cells of endosperm; *e s*, embryo-sac; *int*, developing integument; *o*, egg-cell; *s*, suspensor; *syn*, synergidae. (Enlarged.)

Fig. 41. A small portion of a root, showing its habit of branching as seen under a low magnifying power. (5/1.)

Fig. 42. A somewhat diagrammatic sketch of a longitudinal section of the apex of a rootlet, showing the fungal investment, the various layers of the root-cap, and the exogenous origin of a new lateral root. *c*, cortex; *ep*, epidermis; *f*, the investing fungal hyphae in which are embedded the outer dead layers of the root-cap (dark); *pl*, plerome of root; *pl'*, plerome of lateral exogenous root; *rc*, root-cap (with calyptrogen); *rc'*, root-cap of exogenous root. (100/1.)

Fig. 43. Longitudinal median section of a root-apex, showing origin of layers of root-cap from dermatogen. *c*, cortex; *dc*, dermato-calyptrogenic layer; *ep*, epidermis; *pl*, plerome; *rc*, root-cap; *rc'*, youngest layer of root-cap. (130/1.)

Fig. 44. Radial longitudinal section through the outer part of the cortex, epidermis, and investing fungal hyphae of a root. *a* and *b*, side walls of epidermal cells with hyphae on surface; *c*, cortical cells (some containing starch-granules); *e*, epidermis; *h*, investing fungal hyphae; *n*, rod-shaped nuclei of epidermal cells; *r c*, old layers of the root-cap retained in position by the investing hyphae. (300/1.)

Fig. 45. Tangential longitudinal section through the epidermis of a root, showing *e*, the epidermal cells; *h*, the mycelium investing each cell. (300/1.)

Figs. 46 and 47. Transverse sections of the stem taken respectively 6 cm. and 18½ cm. from the base. The distribution of the vascular bundles in a ring is shown, together with those passing out into the leaves (and in Fig. 47 into the axillary flower-stalks). The irregularity of the peripheral outline is due to the insertion of the closely imbricating leaves. *c*, cortex; *f b*, groups of bundles passing into the flower-stalks; *l b*, bundles passing into the leaves; *p*, pith; *v r*, ring of vascular bundles. (Fig. 46, natural size; 47, 2/1.)

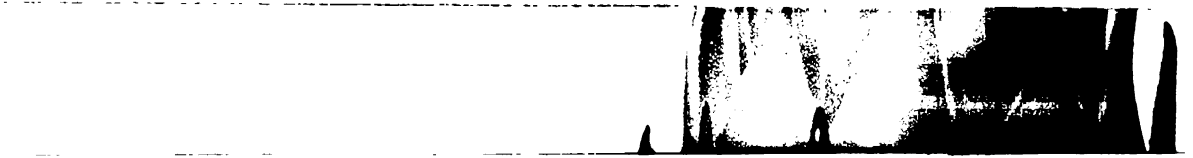
Fig. 48. Enlarged view of a small portion of the ring of vascular bundles, and of the clusters of bundles passing out to the leaves (bracts) and flower-stalks. *c*, cortex; *f b*, bundles to flower-stalk; *l b*, bundles to leaf; *p*, pith; *ph*, phloem; *x*, xylem. (25/1.)

Fig. 49. A small portion of the vascular ring seen under a high power of the microscope. The arrow points towards the centre of the stem. *c*, cortex; *par*, parenchyma; *ph*, phloem; *p x*, proto-xylem; *x*, xylem. (Enlarged.)

Fig. 50, *a*, *b*, *c*, *d*, and *e*. Series of leaves showing transition from one form to another as seen from the outer (under) face. *a*, from the base of the stem; *b* and *c*, from the thick bulb-like portion; *d*, bract subtending an expanded flower; *e*, bract subtending an unopened bud. (Natural size.)

Fig. 51. Margin of a bract, showing the glands as seen under a simple microscope.

Fig. 52. A single gland in median longitudinal section. *c*, cuticle of epidermis. (Much enlarged.)



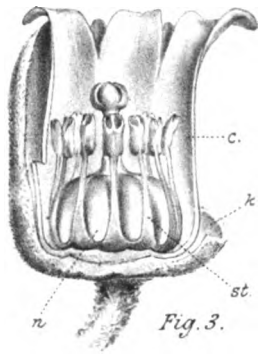


Fig. 3.

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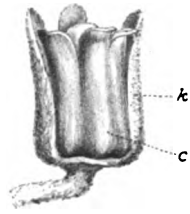

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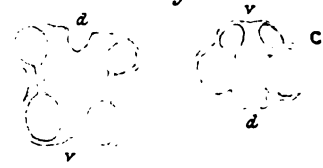

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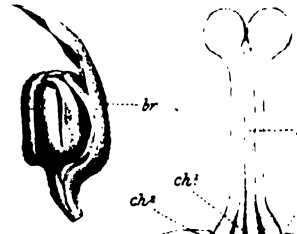

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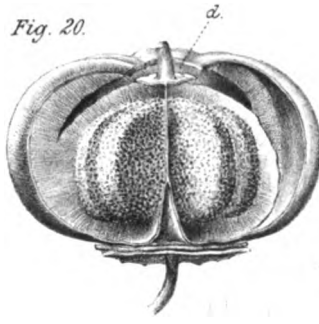

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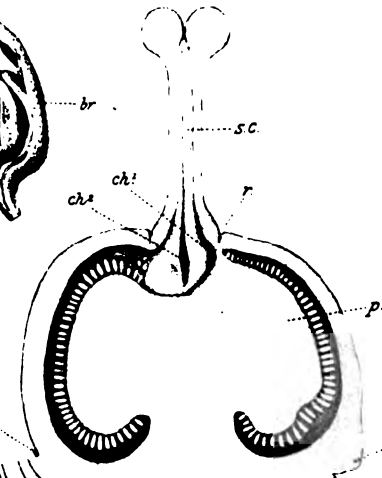

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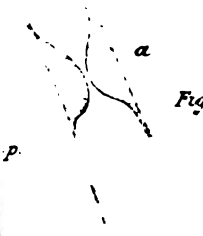

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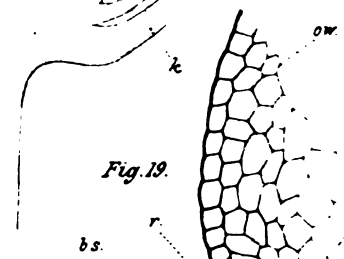
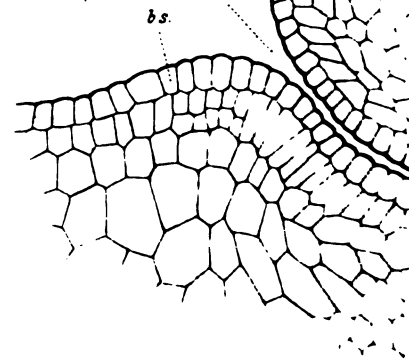
Fig. 18.





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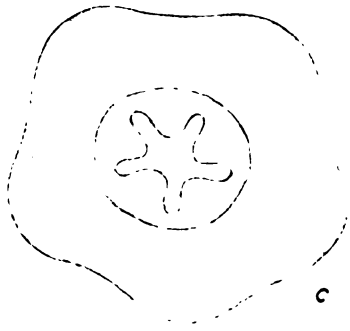

Fig. 21.

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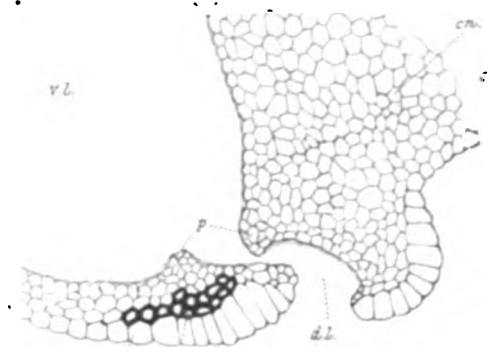
Fig 7



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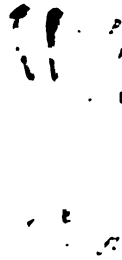

Fig 9

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Fig 11

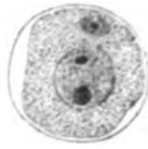


Fig 12

Fig 13.

Fig 14.

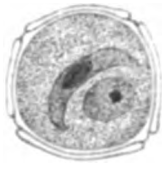
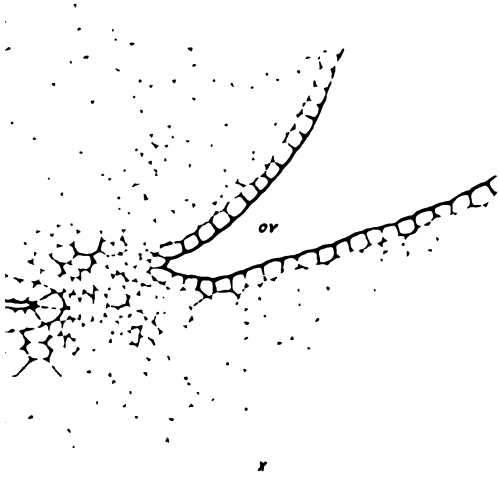


Fig 15



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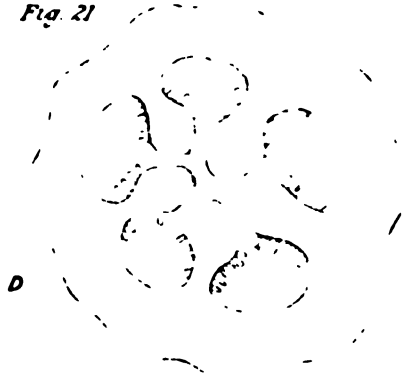

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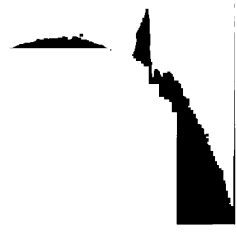


Fig. 21, E.

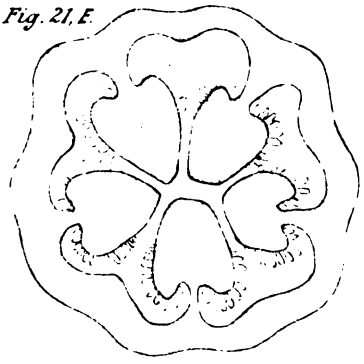
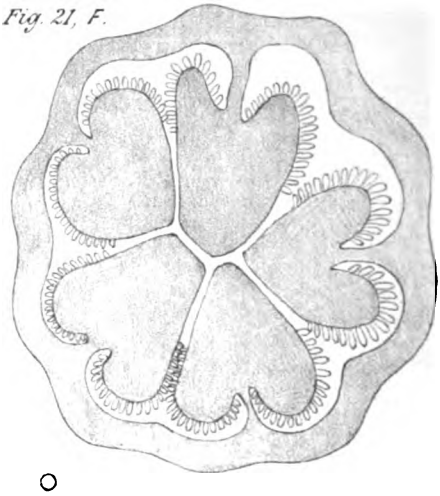


Fig. 21, F.



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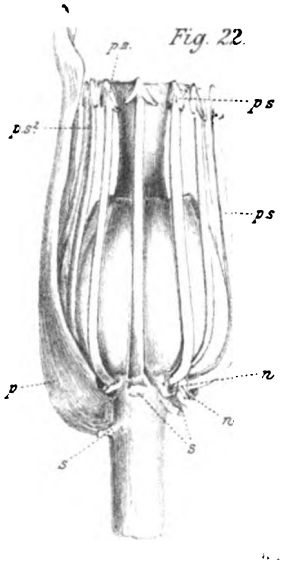

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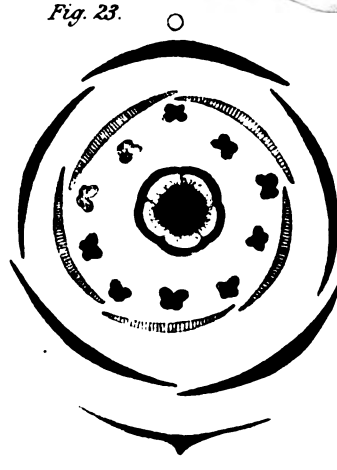

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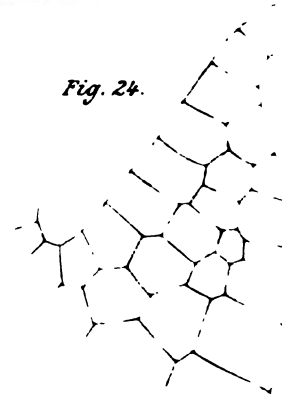

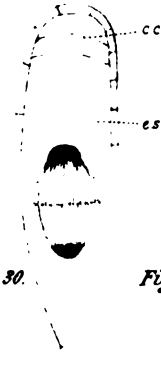

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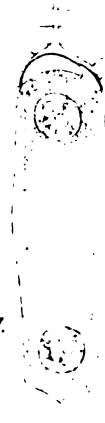

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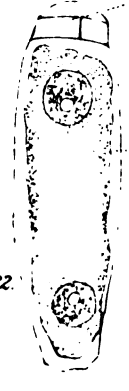

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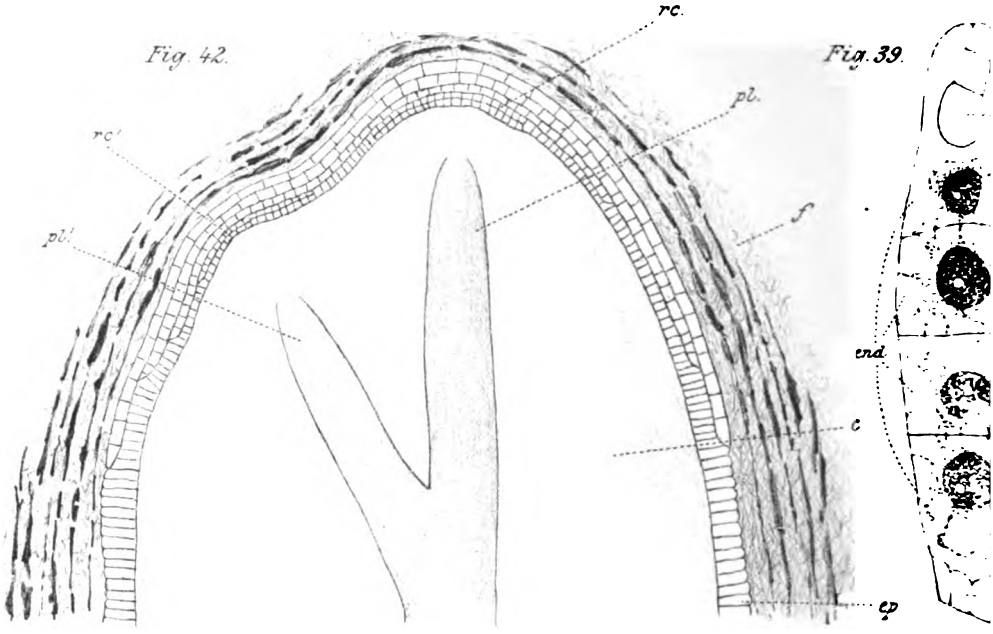

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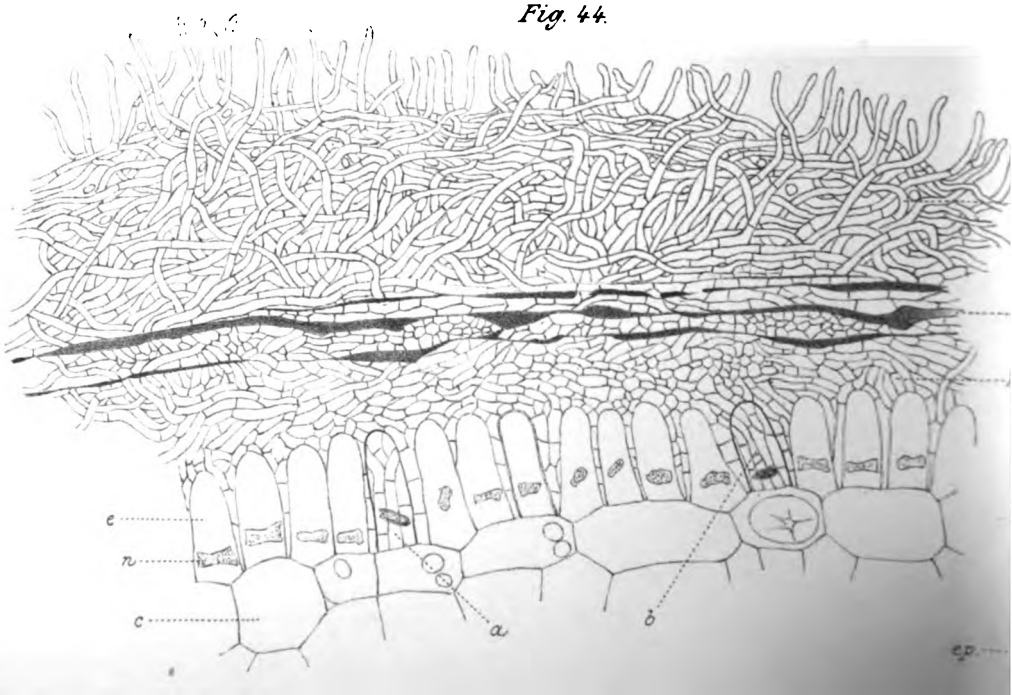

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OLIVER.—ON SARCODES SANGUINEA, Torr.

Fig. 41

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Fig. 40.

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Fig. 43.

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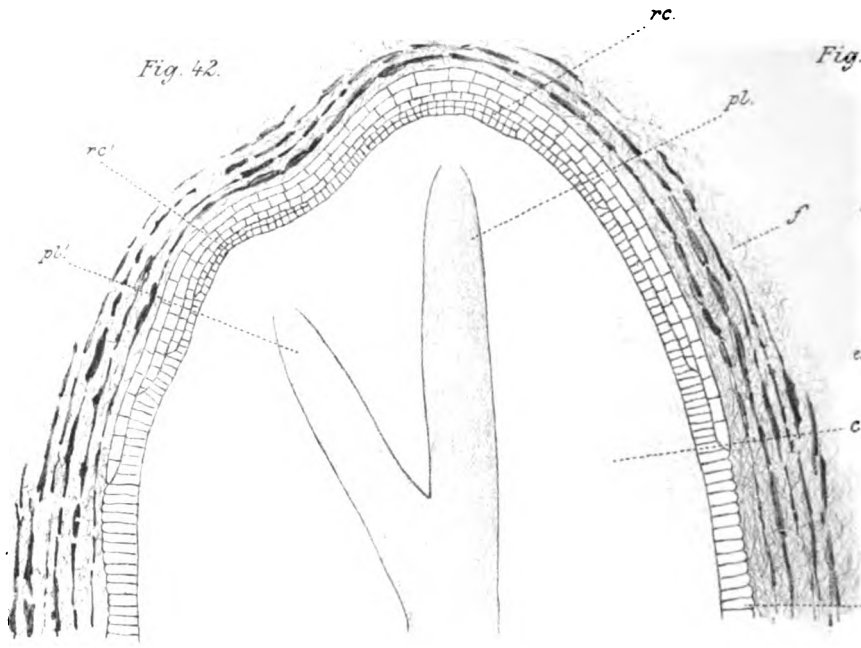
Fig. 42.



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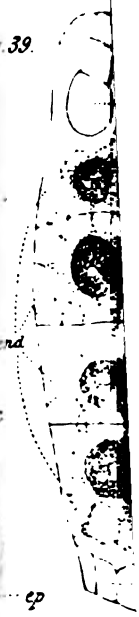

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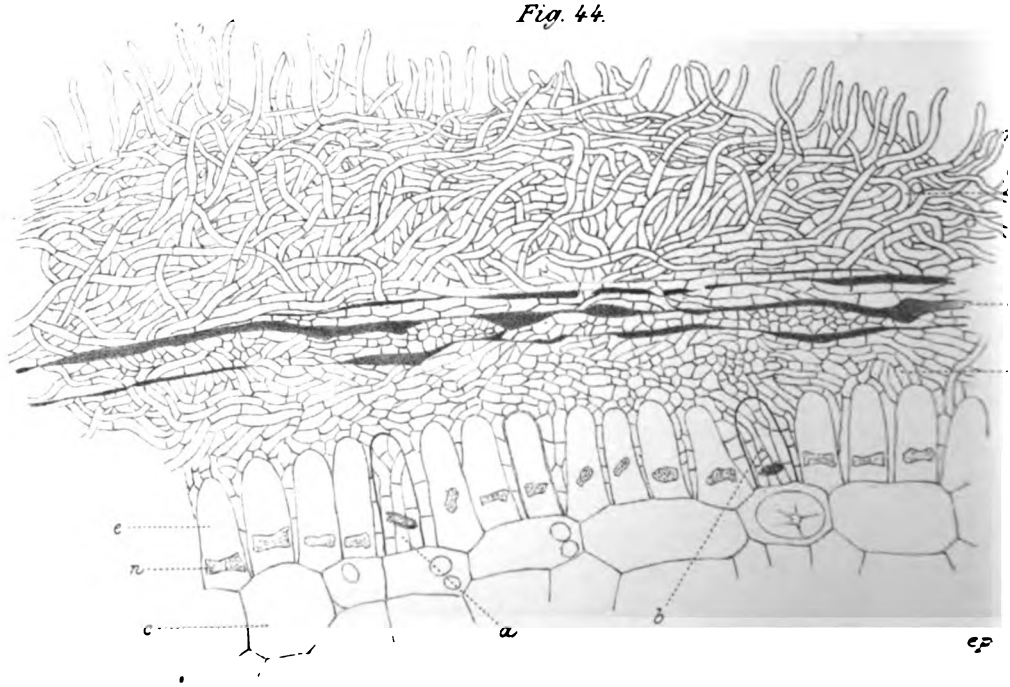

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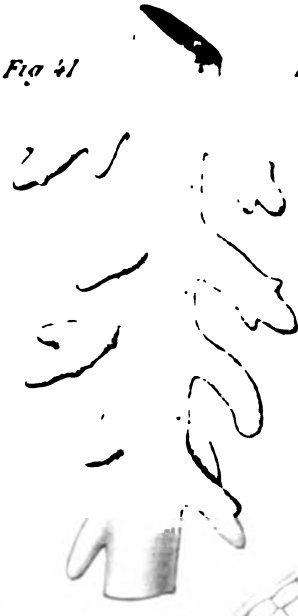
OLIVER.—ON SARCODES SANGUINEA, Torr.

Fig 41



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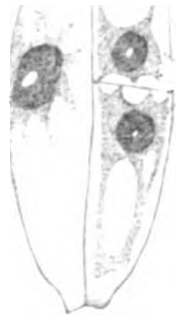


Fig 45

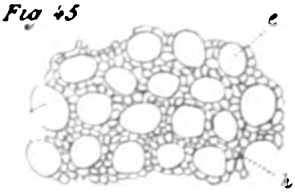
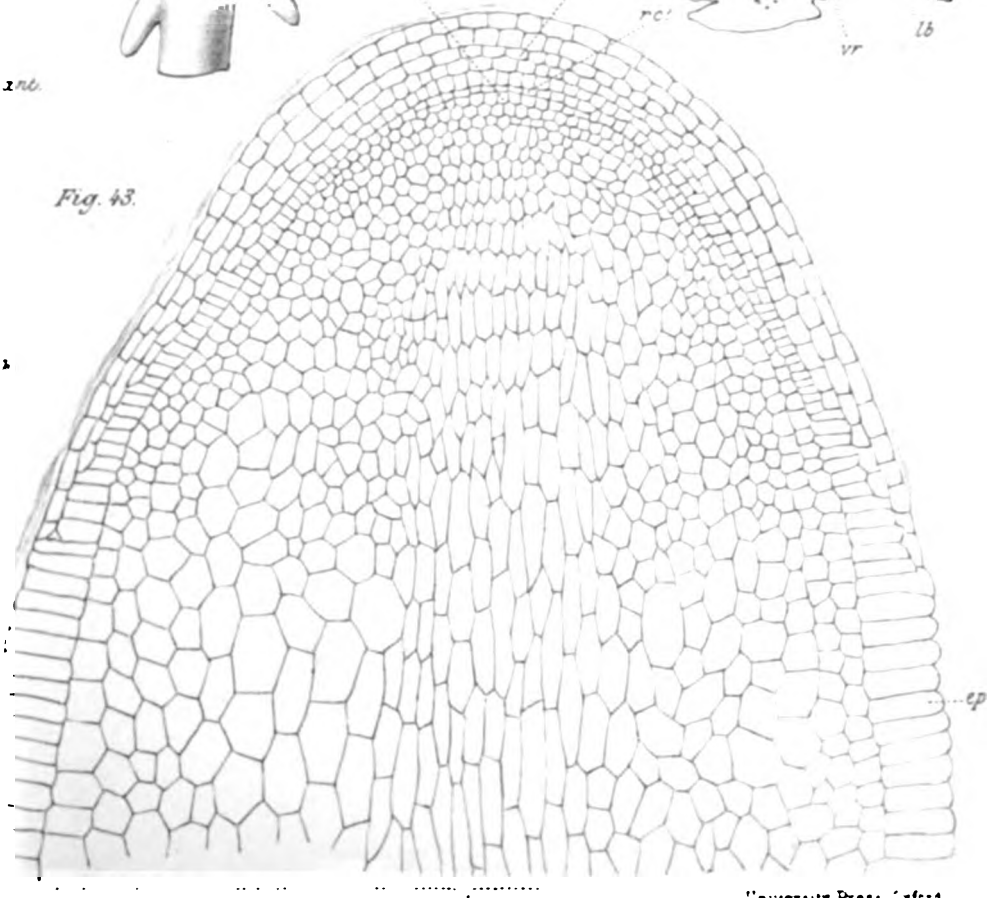


Fig. 46

Fig. 43.



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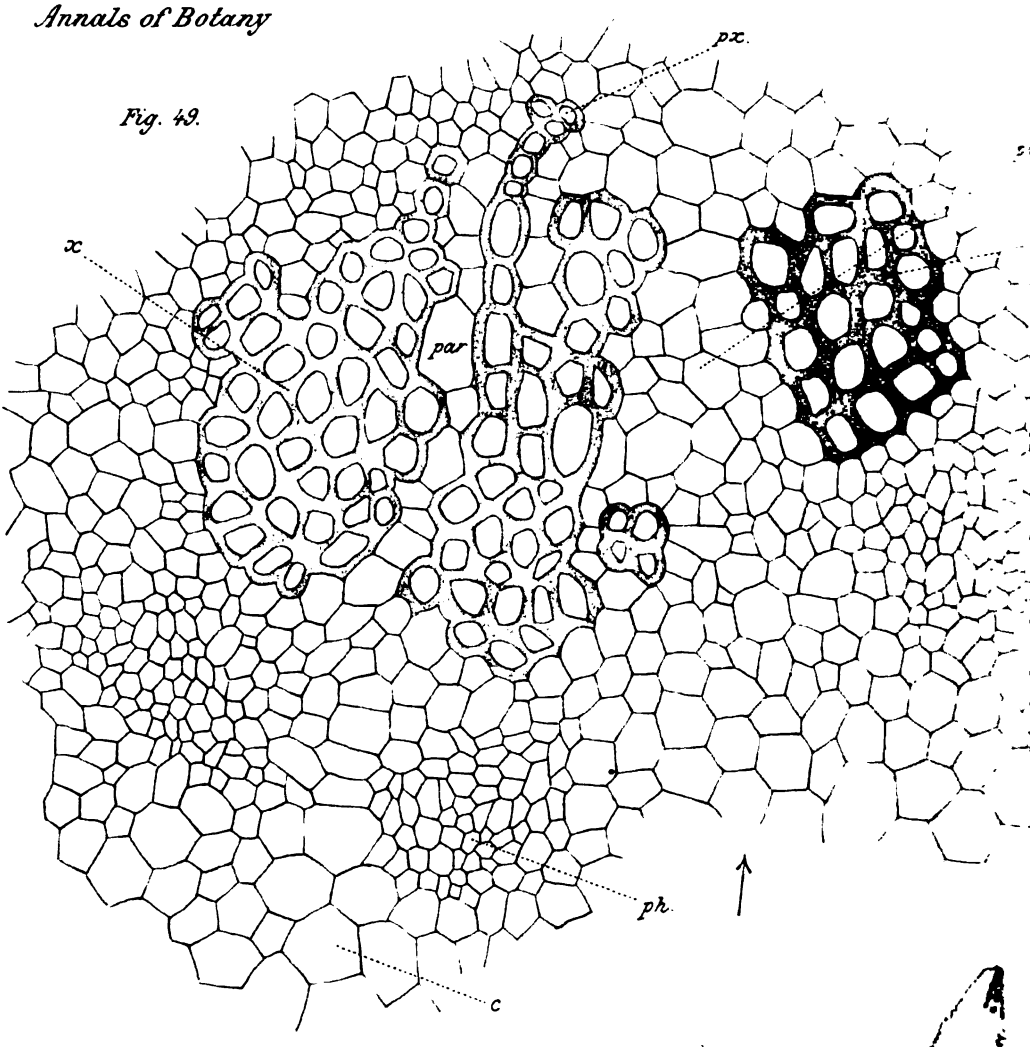

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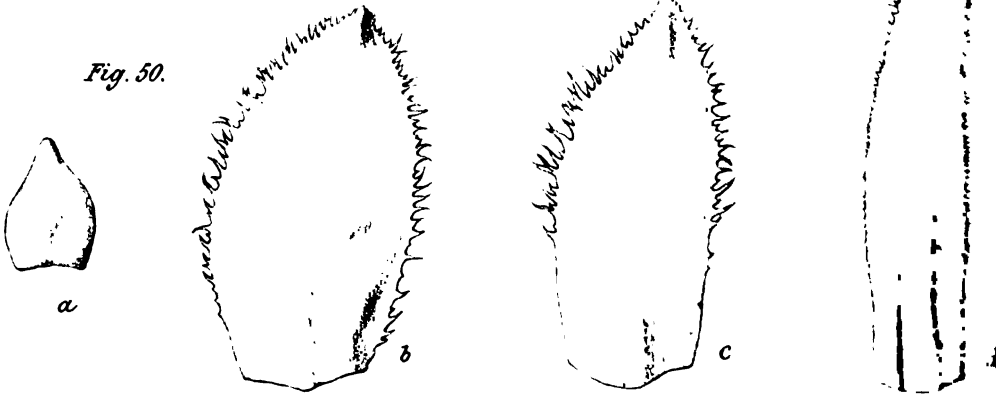

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OLIVER.— ON SARCODES SANGUINEA, Torr.

Fig 48

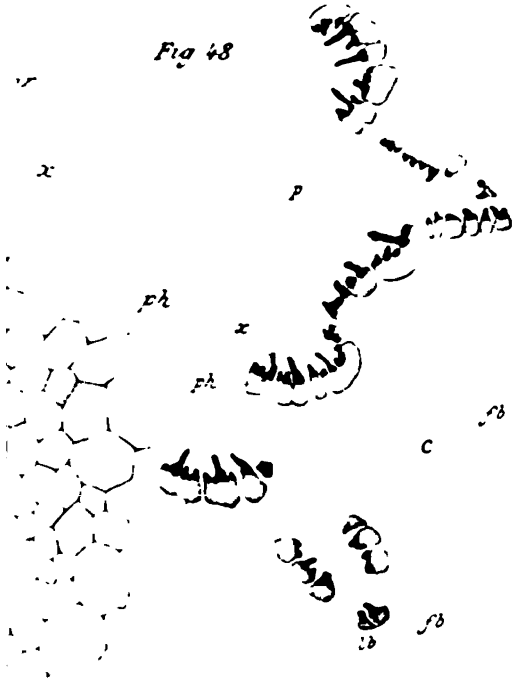


Fig 52

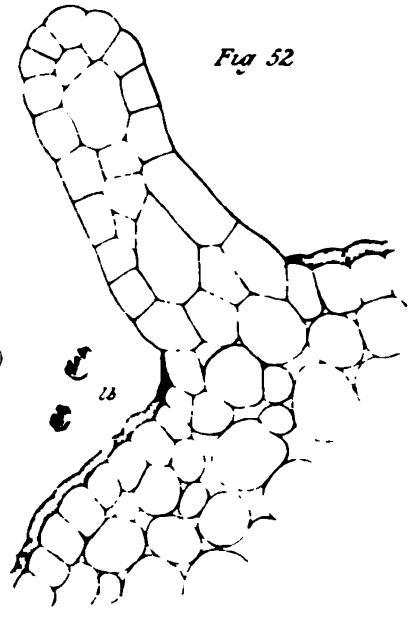
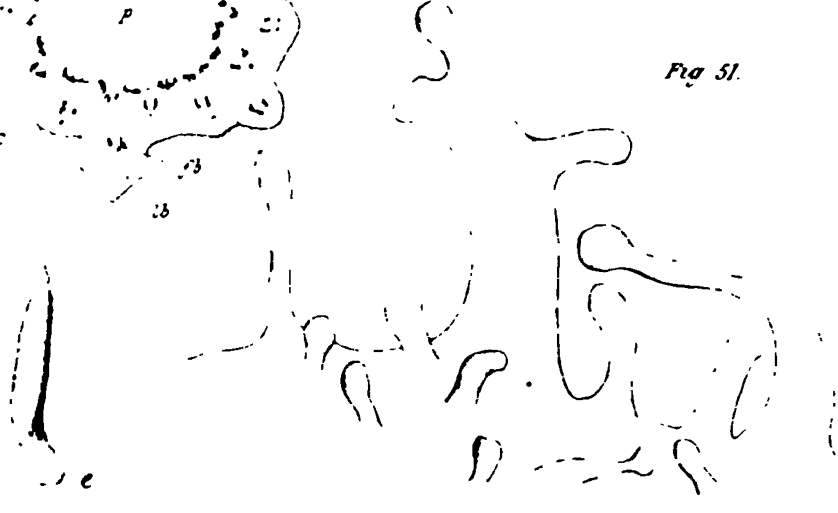


Fig. 47.

Fig 51.



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On the method of fertilization in Bulbophyllum macranthum, and allied Orchids.

BY

H. N. RIDLEY, M.A., F.L.S.

Superintendent of the Botanic Garden of Singapore.

With Plate XXII. A.

ALL who have examined the flowers of any species of *Cirrhopetalum*, or *Bulbophyllum*, cannot fail to have remarked the singular arrangement of the lip, which is usually small and inconspicuous, especially when compared with the lateral sepals, and is so loosely articulated with the prolonged foot of the column as to be exceedingly mobile, frequently being kept in a constant state of vibration by every current of air. How this state of affairs conduced to insect fertilization was altogether obscure. Darwin, in the Fertilization of Orchids, p. 138, states, after examining several species of *Bulbophyllum*, e. g. *B. cupreum*, *B. cocoinum*, and *B. Rhizophorae*, that he was quite unable to conjecture the use of this extreme mobility of lip, unless it were to attract the attention of insects; adding that possibly in the case of *B. barbigerum* and a few other species in which the lip is decorated with tufts of very delicate clubbed hairs, this may play some part in calling the attention of the fertilizer. But I shall hope to show an entirely different reason for this arrangement, which, especially in the case of *B. macranthum*, is I think one of the most beautiful and marvellous among all those in the Order.

[Annals of Botany, Vol. IV. No. XV, August 1890.]

B. macranthum, Lindl. In this species the following organs are concerned in the process of fertilization. The lip is very small in proportion to the sepals. It is a curved tongue-shaped fleshy organ, acute at the apex and squared at the base, where it has two little projecting angles or ears, and a central groove. It is light yellow, the apex speckled with red, and is not smooth and polished like the sepals. The squared base is notched and balanced upon the apex of the column-foot, so that it hangs half through the aperture between the two sepals. It is prevented from falling quite through by the little ears which rest on the inner edges of the two sepals. It moves easily backwards and forwards upon its hinge, but in whatever position the flower is held, the lip always remains in the normal position, as shown in Figs. 3, 4, the centre being 4 mm. from the column. But a certain amount of weight placed between the ears causes it to fall backwards towards and nearly to touch the column. The column is a little more than 5 mm. in height, stout, and rounded at the back. The stelidia are short triangular processes, rather thin in substance but stiff; they stand out towards the lip, but slightly converge together at the apices, which are 2 mm. apart.

The anther is sunk in the clinandrium, and turned on its back, so that the apex touches the back of the clinandrium and the pollen-disc is exposed between the two stelidia. The pollen-masses are two, rather large, bright yellow, semi-transparent, pyriform, curved, bilobed.

The column is yellow, with a fairly long up-curved foot, the apex of the anther is red. From the position of the foot, which is curved upwards nearly to the height of the stigma, the squared base of the lip stands a little above and at some distance (4 mm.) from the stigma and pollen.

The fertilizer of this orchid is a small and active fly (Dipteron); it is diurnal, and delights in bright sunshine. I have seen it invariably close by when this plant is in bloom, and it also makes its appearance when *Dendrobium superbum* and another smaller flowered Sestochilous *Bulbophyllum*, which I

[1] Bot. Reg., 1844, t. 13.

have not identified, are in flower. I have never seen it at other flowers of any kind, nor have I ever found it elsewhere, except on one or two occasions when I have taken it on the white ceiling of my verandah in the heat of the day. But in whatever part of the house or garden any of these plants are in blossom, there will always be seen one or more of these flies, unless the weather be too dark or wet for them. The three orchids I have mentioned have but little in common, but they have all a certain amount of deep red colour in the flowers, the little *Bulbophyllum* last mentioned being entirely dark speckled red, and the *Dendrobium* having two deep red eyes at the base of the lip. They also all possess a very strong scent; *B. macranthum* that of cloves, the others of Turkey rhubarb. I endeavoured to find out which was the most important of these characters, by scenting pieces of dark maroon leaves and other objects with oil of cloves, but the flies took no notice of them, although the two scents are, to my senses, very similar.

The insect usually commences by licking with its short tongue the upper part of the sepals, both back and front. It eventually settles down to the front of the lateral sepals, especially on their dark coloured grooved apices. As long as it is at work in the narrow upper part of the sepals, it can hold on to their edges, but when it gets to the broad part, it cannot reach across. Its feet slip from the glassy surface, and it clutches wildly at the lip. Immediately its weight falls upon the lip the latter suddenly drops back, pitching the insect stern first into the column between the stelidia, which have enough springiness in them to separate a little and then close tightly on the abdomen of the captive (Figs. 5, 6). The insect strikes the disc of the pollinia with the upper part of its abdomen and the pollinia become fixed with exact precision upon the first segment, the lower part of the abdomen generally adhering to the stigma; the lip, released by the astonished fly, instantly returns to its original position, and the insect is left struggling on its back in the arms of the column; soon, however, it extricates itself, and flies away with the pollen on its back. As the

insect generally begins at the tips of the sepals, by the time it has got into the position for fertilizing the flower it has licked the sepals quite clean; so it flies off to another one, where the same operation is repeated, and the pollen placed upon the stigma of the second flower. The fly with the pollen upon its back is less active than when free, the pollen apparently being an appreciable weight to it; and it seems to me probable that, owing to this extra weight, the fly may on a second visit fall off the lip more rapidly, and so, falling a little lower, strike the stigma with the part of its abdomen with which it struck the pollinia before: but this I have not been able definitely to prove, and indeed there is the less need for it, because it must be remembered that when the fly strikes the viscid disc of the pollinia, the latter are at right-angles to its body; but when they are extracted, they fall by their own weight and lie at full length upon the insect's abdomen, which they partially cover.

It is essential that the fly's whole weight should be thrown upon the lip; one or two of its legs will not do, and smaller insects, as an ant or a thrips, will not pull over the lip. And a considerable amount too of pressure upon the pollen is required. A fly wandering about the sepals often puts its wings into the stigma, or on the pollen-mass, but does not move it. In one form of the plant which I have seen, from Borneo, the flower is much smaller, and shorter. In this case the arrangement is less successful, because some of the flies can reach quite across the broadest part of the sepals and hold on by the edges, so that they do not slip at all. It is therefore a decided advantage to the plant to have the flowers of large size, but the small-flowered form has one advantage, and that is a saving of time; for there being so much less area of food-supply it takes a much shorter time for a fly to work over the sepals in this form than in the other. I watched one fly for over an hour before it got into a position for fertilizing the flower, and long before this occurred, a fly appeared from a neighbouring plant with smaller flowers with a pair of pollinia upon its back. I should state, however, that three or four flies

were at work upon the smaller flowers and were jostling each other in close proximity to the lip. This saving of time is of considerable importance. The flowers only last two days at the outside, and a heavy shower of rain may come at any minute and spoil them. Besides, the mechanism of the lip is liable to get out of order, and it will not move properly after the flower has been open some time, if it gets at all dry. Although the mechanism is so beautifully arranged it does not always succeed. I have seen a fly twice running thrown from the lip without striking the pollen-masses. This was because it managed to use its wings before it reached the column, and so flew off. But it returned each time, until on one occasion it was not quick enough and was caught.

I examined the sepals carefully with the microscope to see what it was the flies obtained, and made transverse and longitudinal sections of the upper portion. The upper surface of the sepals is covered with an exceedingly thin layer of delicate, rather narrow and elongate cells, quite transparent and apparently empty. Beneath these is a layer of thicker and broader cells full of granular matter, which readily escapes when a section is made of the sepals; below these again is a layer of coloured cells. There are no definite saccharine glands; but, as far as I was able to make out, there seems to be an exudation of nectar on the surface of the sepals, perhaps analogous to honeydew, which seems to come from the second layer of cells. I was unable to detect any sweetness of taste on the sepals, and they always appear to be quite dry. One cannot help being reminded of the shining black bosses at the base of the lip in *Ophrys muscifera*, which has been seen (Hermann Müller, Fertilization of Flowers, p. 535) to be visited by a species of Dipteron (*Sarcophaga*). And one may reasonably doubt whether these and similar bodies are really sham nectaries, as Sprengel, Darwin and Müller seem to have imagined; for we have in this *Bulbophyllum* a flower with no visible nectar regularly visited by a species of Dipteron only seen besides on two very similarly constructed flowers; and furthermore this insect is evidently not disappointed in its

search, for it spends hours licking this flower, and if driven away speedily returns, nor will it visit a flower which is beginning to wither.

It is interesting to note that *Dendrobium superbum* is not a native of these regions, and so cannot strictly speaking be known to the native Dipteron, yet the insect, although evidently very particular in its tastes, is very quickly attracted to it. Another point is worthy of note in connection with the *Bulbophyllum*. In most of the species of the genus the lip is darker coloured than the rest of the flower, or at least more conspicuously ornamented; but here the conspicuous colouring is transferred, so to say, to the sepals, which are the attractive portion, though there are traces of the red colouring of the lip still left upon the apex of the inconspicuous lip. I do not believe that there are very many *Bulbophylla* that are fertilized exactly in this way. Nearly all the species, including most at least of the *Sestochilus* section, have the ovary twisted, and the lateral sepals thus hang downwards instead of being turned up as they are in *B. macranthum*; and the closely allied *Cirrhopetala* and *Megaclinia* have the same arrangement.

The *Cirrhopetala* are very rarely fertilized even in their native haunts, although they flower well and constantly. Many of the smaller *Bulbophylla*, however, constantly fruit, and I recently found a small species in the act of being fertilized by a small red Dipteron. This, *B. striatellum* mihi, is a small creeping plant with very slender filiform scapes bearing solitary terminal flowers. The three sepals are all similar, lanceolate with a filiform apex, half an inch long, connivent, yellow with red stripes. The petals shorter, oblong-lanceolate, stiff with rounded apices, and similarly coloured. The lip is loosely articulated with the foot of the column, very small, dark red purple, tongue-shaped, curved and fleshy. It is quite invisible from the outside, from being shorter than the sepals, which conceal it. The column has the usual shape, but possesses two setiform erect stelidia. As I have seen only a single flower, I cannot

give so detailed a description of its fertilization as I could of the preceding species. It appears, however, that a minute fly enters the flower between the sepals, presumably in search of nectar, and climbs upon the nicely balanced lip, with its head towards the base of the lip. Its weight overbalances the lip, and it is thrown headfirst into the arms of the column (Figs. 7, 8). The stiff erect petals play the part assigned to the stelidia, preventing the insect's escaping on either side, and the pollinia are planted between its eyes (Fig. 9). In this plant the insect cannot use its wings on account of the sepals being too close together, so that when once it gets on the lip it must go headfirst into the column. In these small-flowered species it is absolutely essential that the lip should be very delicately balanced, on account of the very light weight of the small fertilizer, and this I believe is the reason of the extreme mobility of the lip. I do not think it plays any part in attracting insects, although it is true that the lip quivers more in the species with open flowers than in those with closed or partially closed ones. But in the latter case the insect cannot use its wings, so that, even if the motion of the lip is slow, it is quite sure, and the fly cannot avoid falling with its head on the column. On the other hand, in open-flowered plants like *Cirrhopetalum* the fertilizer must be taken by surprise, and be suddenly pitched off, or it would escape; and for this it is essential that the lip should be exquisitely balanced.

In the typical *Cirrhopetala*, e.g. *C. Cumingii*, the lateral sepals are connate for most of their length, and the lip hangs in the space between their bases. The sepals are the most conspicuous portion of the flower, and it is probable that they form the alighting place of the fertilizer. The lip is separated from the margin of the sepals in front by a considerable space, so that a small insect wishing to get at the nectar at the base of the lip cannot do so without getting upon it. There is a small-flowered species of *Cirrhopetalum* here which is of very remarkable structure, and is apparently undescribed, in which I have seen the fertilizer at work. This species has the

dorsal sepal and petals ciliate along the edges and ending in long points, the lateral sepals form a funnel-shaped body ending below in two very long setae; all are dark red, with a little yellow at base. The lip is violet, lighter in the centre, and very conspicuous against the dark red petals and sepals. It seems to be glutinous and shiny. After the flowers were opened I found a very small black Dipteron, resembling a minute *Musca*, upon the lip. It was seated on the apex of the lip with its head towards the column, and appeared to be licking the lip. Presently it moved towards the lip-base, and as it did so the lip suddenly went over, throwing the fly into the column, where it stuck, the lip remaining in the same position. I attempted to secure the fly, but it released itself, and escaped without removing the pollen, and the lip sprang back to its old position. Probably I had touched the lip and so set the insect free, and if it had been left to extricate itself, it would have received the pollen upon its head in its struggles to escape. Shortly before this, while watching another species of *Cirrhopetalum*, also undescribed, I saw a similar fly, this time upon the broad flattened lateral sepals, which it was carefully examining. In the latter species which is an ally of *C. Cumingii*, and much resembles *C. pulchrum*, N. E. Brown (figured in the Illustration Horticole), but is smaller, the lip is dark-coloured, while the rest of the flower is comparatively light-coloured. The attractive part here is certainly the sepals.

Now to compare the principles of fertilization of a typical *Bulbophyllum*, such as *B. adenopetalum* or *Medusae*, with that of a *Cirrhopetalum*. In the first case the flower is partially closed, and the lateral sepals only serve to narrow the apprasch to the column. In the second case they frequently perform the function usually allotted to the lip, i. e. of an attractive alighting place. They are of different colour and form to the dorsal sepal, and much larger. The petals seem to play the same part in both, they are more inconspicuous, smaller, stiff, often in the latter case armed with cilia; in *B. Epicrianthes* they are reduced to a tuft of cilia, and serve to prevent the

escape of the fertilizer, and also I believe to put an obstacle in the way of its obtaining the nectar on the lip from the side of the flower. The lip in both is conspicuously coloured, at least if the flower is at all coloured. The balancing principle is the same in both ; but in *Cirrhopetalum* it is more perfectly arranged, since being nowhere in apposition with any other part of the flower, it is necessary that the fertilizer should trust itself wholly to the lip in order to get at the nectar with its short tongue, and also, for the same reason, there is no risk of friction with the petals or lateral sepals, so that the mobility is not at all impaired.

The flowers, especially the thinner-textured ones, last from 24 to 48 hours only in a fertilizable state, after which the lip becomes stiff and does not work properly. It is, however, rare for any orchid flower to survive the second day in its native haunts here; under any circumstances it will be effete forty-eight hours after opening, and usually in a very much shorter time.

In conclusion, taking the whole group of Bulbophylleae, including *Cirrhopetalum*, I do not doubt but that they are intended altogether for Dipterous fertilization. There is always a tendency to that dark red colouring so much associated with plants attractive to flies, as *Amorphophallus*, *Rafflesia*, *Arum*. The nectar too is not placed in a sac or tube, but on an open flat body, and is exuded in small quantities, so as to be easily licked off by Diptera. The nearly allied genus *Dendrobium*, on the other hand, is adapted for Bee-fertilization, and consequently the arrangement, structure, and colouring of the flowers are quite different.

B. striatellum, nob. Planta pusilla, rhizomate filiformi tenui longe repente. Pseudobulbi curvi, conici, pallide virides, vix ½ unc. longi, ¼ unc. dissiti. Folium erectum, lanceolatum, acutum, 2 unc. longum, ¼ unc. latum, subtenue. Scapus filiformis, pseudobulbo vix superans, vaginis 1–2 ad basin. Flos terminalis, parvus, clausus, nutans, pedicello unciali rubro. Sepala similia, oblonga vel oblongo-lanceolata, caudata, flava carinis tribus rufis, semi-unc. longa. Petala

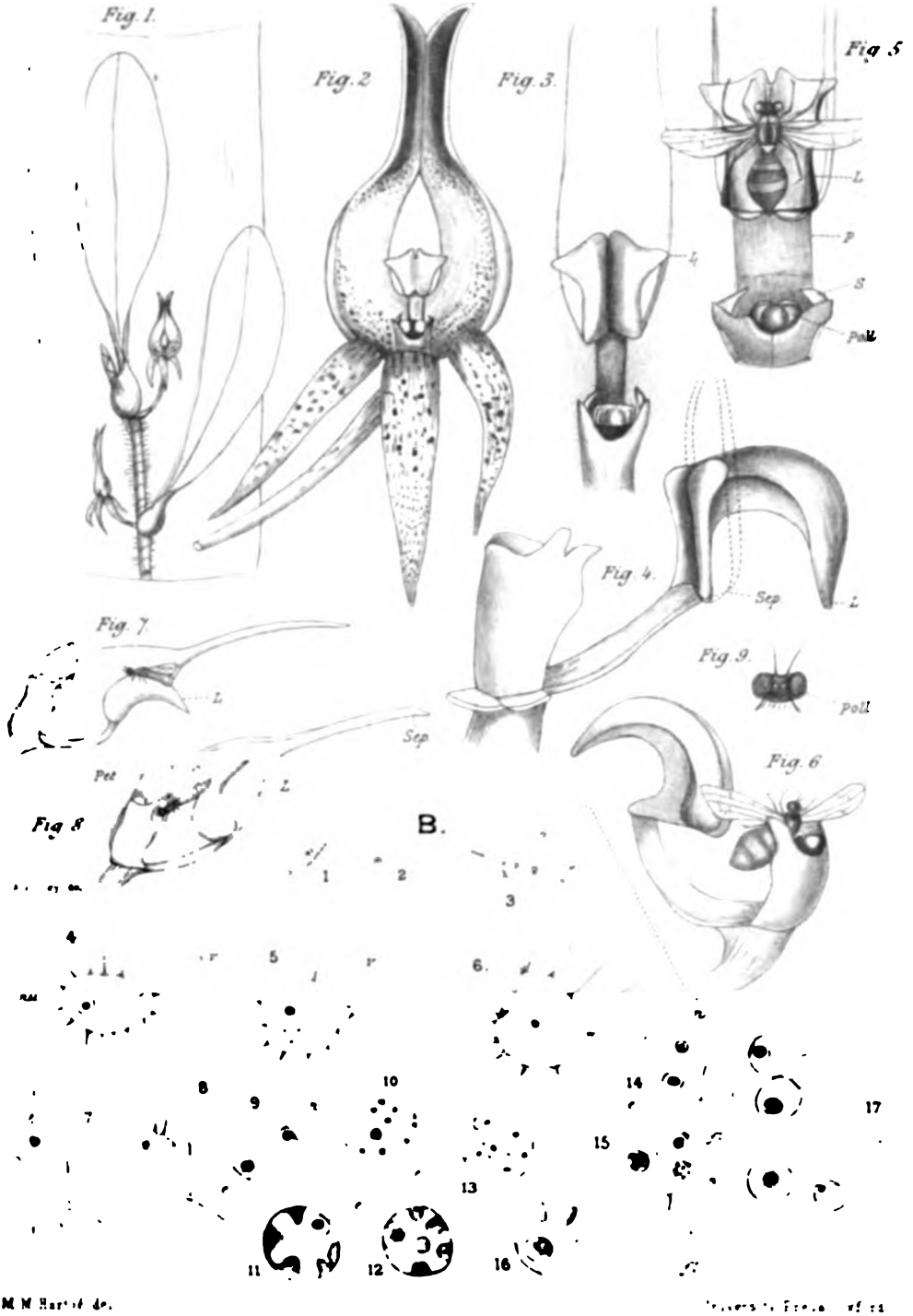
ovato-oblonga, apicibus rotundatis, sepalis (caudis exceptis) paullo brevioribus, colore similia. Labellum multo brevius, angustum, lineare, carnosum, recurvum, subtus pubescens, flavum apice rubro punctatum, basi punctis rubris duabus. Columna brevis; stelidiis brevibus obtusis.

Singapore, on trees at Char chu Rang.

EXPLANATION OF FIGURES IN PLATE XXII. A.

Illustrating Mr. H. N. Ridley's paper on the method of fertilization in *Bulbophyllum macranthum* and allied Orchids.

Fig. 1. *B. macranthum.* Whole plant very much reduced.
Fig. 2. Flower slightly enlarged.
Fig. 3. Lip and column from behind, enlarged.
Fig. 4. Lip and column, side view.
Fig. 5. Lip and column, with fly upon the lip. *L.* Lip; *poll.* pollinia; *p.* foot of column; *S.* stelidium.
Fig. 6. Fly thrown into the arms of column.
Fig. 7. *B. striatellum* mihi. Side view of flower much enlarged. Dorsal and one lateral sepal and one petal removed, with fly on the lip.
Fig. 8. The same after fall of the lip.
Fig. 9. Head of fly with pollinia between the eyes.



M. M. Hartog del. Printed by Francis Bedford

A. RIDLEY.—ON FERTILISATION IN BOLBOPHYLLUM.
B. HARTOG.—ON A PARASITIC MONADINE.

A Monadine parasitic on Saprolegnieae[1].

BY

MARCUS M. HARTOG, M.A., D.Sc.

Professor of Natural History, Queen's College, Cork.

With Plate XXII. B.

IN my cultures of Saprolegnieae I was for a long time perplexed by structures which looked like abnormal spores with a gigantic nucleus, and which I at first really regarded as such. However, on making cover-glass cultures of 'cuttings' (fragments of mycelium removed with a blunt knife) with young oogonia, I found to my cost that they were parasitic organisms, which demanded careful study. They soon turned out to be members of Cienkowski's group 'Monadineae,' now regarded as the close allies of Myxomycetes; and, so far as can be judged from the vegetative conditions and zoocysts, are referable to the well-named genus *Pseudospora* Cienk.[2], created in 1865, to receive very similar parasites on the green Conjugates and Desmids. The organism is so abundant in cultures of Saprolegnieae that it could not escape the notice of previous observers. Pringsheim[3] first saw the zoocysts in *Saprolegnia* (*Leptomitus*) *lactea*, and figured them in company with the undestroyed cellulin-corpuscles in an empty hypha. He describes them as 'Eine grosse Anzahl stark mit Inhalt erfüllter kugeliger Zellen . . . die offenbar keine Schwärmsporen sind. Ihre Bedeutung ist mir noch unbekannt.'

Lindstedt in 1872, in his 'Synopsis Saprolegniacearum,' recognised their true nature. 'In älteren Fäden deren fand

[1] Read at the British Association, Newcastle-on-Tyne, 1889.

[2] Beiträge zur Kenntniss der Monadinen, in Schultze's Arch. f. Micr. Anat. i. 213.

[3] Jahrbücher, II. 234, t. xxiii. f. 6.

ich mehrmals die von Pringsheim bei *Leptomitus lacteus* erwähnten kugeligen Zellen. . . . Diese Zellen sind von verschiedener Grösse, aber gleichartiger kugeliger Anstalt; die kleineren sehen wie homogene Protoplasmatropfen aus, die von einer sehr zarten Membran begränzt scheinen; in der grösseren befinden sich in der Mitte mehrere dichte Körperchen von unbestimmter Anzahl, doch nicht 4 übersteigend. In einem einzigen Falle bemerkte ich zwischen solchen ruhenden Zellen auch bewegliche, die sich in Form und Grösse von diesen nicht unterschieden. Diese Erscheinung deutet darauf hin, dass die kleinen Organismen Monaden sind. . . . Identificirt mit einer der von Cienkowski aufgestellten Arten konnte diese Monade nicht sein, sie entzog sich bald ganz der Beobachtung.' It is obvious that neither the proper flagellate nor the amoeboid stage was seen by our author; but his instinctive recognition of its systematic position merits that I should attach his name to the species.

For another decade the organism remained unnoticed, so far as I know, till Pringsheim [1] described and figured certain amoeboid structures as differentiated in the antheridial tubes of *Achlya*, and escaping into the oogonia presumably to fertilize the oospores; he therefore termed them 'sperm-amöben.' Zopf [2] at once took up the cudgels in favour of the parasitic nature of the spermamoebae, and in connection therewith referred to what are certainly the monadines we have to deal with; but, though he promised a fuller paper, it has not appeared to the best of my knowledge, though in his monograph, 'Die Pilzthiere oder Schleimpilze,' published in Schenk's 'Handbuch der Botanik' in 1887, he makes a further allusion to the controversy. Pringsheim answered the challenge [3], but an account of the discussion, so far as it bears on our species, is best deferred till we have studied it in detail.

[1] Neue Beobachtungen über den Befruchtungsact der Gattungen *Achlya* und *Saprolegnia* in Sitzungsber. d. k. Akad. d. Wiss. zu Berlin, 1882, 855, t. xiv.

[2] Ueber Parasiten in den Antheridien Oogonien und Oosporen der Saprolegnieen, in Botan. Centralblatt, xii. 356.

[3] Ueber die vermeintlichen Amöben in den Schläuchen und Oogonien der Saprolegnieen, in Bot. Centr. xiv. 378.

The first stage I shall describe is the mastigopod swarmer, or zoospore, which may frequently be found in and about the infested hyphae of old cultures about 9 o'clock in the evening, or later. It is oblong (7–10 μ long), acute in front (Figs. 1, 2), with one or two anterior flagella, blunt behind or acute with posterior tractellum; in this variability it resembles the type-species *P. parasitica*, as indeed in almost every respect. Each has a nucleus of the rhizopod or myxomycete type, i.e. vesicular with the nuclein in a spherical central mass; and there is at least one contractile vacuole anterior to the nucleus. They swarm hither and thither in the hypha for a long time before escaping, and then swim about freely in all directions. Being usually formed in closed hyphae they must escape by boring through the wall by the emission of a pseudopodium, but the actual escape has eluded my observations. After a prolonged period of active swimming, less rapid and peculiar than that of Chytridian swarmers, they settle down on the walls of living hyphae, glide along them amoeba-fashion, and finally penetrate into them. I have not seen the full process of penetration; but in several cases I have seen the amoeboids emit a long pseudopodium through the cell-wall and parietal protoplasmic investment of the living hypha and wave for some time in the lumen (Figs. 7, 8). We can scarcely doubt but that the rest of the body follows suit after the fashion of a white blood-corpuscle in diapedesis, but, of course, inversely. The aperture must be elastic and closes completely, possibly by secretion of cellulose from the fungal protoplasm; for there is no loss of turgescence in the hypha so attacked. The stage we are at now is usually termed 'amoeboid'; but '*Heliozooid*' would be the better term, since the pseudopodia are always radiate and stiffish, as in most of the *Monadinae*.

The amoeboids may exist in large quantities in the hyphae, probably from simultaneous or consecutive attacks of numerous swarmers. Without denying the possibility of multiplication by fission in this stage (as occurs in *P. parasitica*, according to Zopf) I must state that I have never seen any indications of it. From the figures (4–8) may be seen the very characteristic

forms assumed at this stage. From theoretical considerations I had not anticipated that the contractile vacuoles would be retained as such in the cell-sap of the living fungus; but this was not confirmed, for they persist, and may be seen to arise afresh after systole by the confluence of two or three very minute vacuoles on their previous site (Fig. 3).

The changes in the infested hyphae are very noteworthy. First of all, the microsomes diminish rapidly in number, so that the protoplasm becomes much more hyaline; granules, with rapid Brownian motion, appear in the hitherto limpid cell-sap. During this stage the nuclei are unaffected, and owing to the decrease of the microsomes (which normally mask them from view) may be readily studied in the living state, as I have stated elsewhere [1]; the protoplasmic currents persist on the walls and in the threads traversing the lumen. The protoplasm is gradually reduced to a granular *débris*, or finally disappears entirely. The cellulin-corpuscles are completely unaffected, and remain to the last, which is not the case in the normal formation of zoospores or oospores in the Saprolegnieae, nor in hyphae of *Achlya* affected by the Chytridian *Woronina polycystis*. In some cases I have seen dumbell-aggregates of minute needle-shaped crystals in such exhausted hyphae. It not unfrequently happens that when a hypha is attacked in one part, the unaffected end protects itself by a transverse wall of protoplasm, which usually bulges out; and the healthy part very frequently emits a narrow hypha, which grows thyllus-fashion into the cavity of the affected part.

During their growth the amoeboids can migrate, leaving one hypha to enter another; that figured in 7 and 8 is obviously, from its size, not the direct transformation of a young zoospore.

After the nutrient protoplasm is used up, that of the parasites has become coarsely granular. Soon the pseudopodia are retracted, and the granules become collected into a highly refractive excrementitious mass, surrounded by a clear vacuole,

[1] Recherches sur la Structure des Saprolegniées, in Comptes Rendus, April 5, 1889.

and simulating a gigantic nucleus. These granules stain deeply with nuclear stains (borax carmine, haematoxylin, nigrosin), and are obviously nitrogenous (can they be the undigested nuclein derived from the nuclei of the host?). The pseudopodia are retracted, and the body rounds off and becomes spherical. At this and subsequent stages of the zoocyst a long flagellum may be protruded, giving rise to the sluggish movements of the body (Figs. 14, 15), seen by Lindstedt. The spherical mass soon becomes infested by a membrane, which is probably chitinous, as it neither swells nor stains blue in the Schultze solution of iodine. It is in this stage, that of the 'zoocyst,' that the species has been noted by my predecessors. Zoocysts may be found lying free in the *débris* of old cultures as well as inside the hyphae. In my balsam mounts of Saprolegnieae these zoocysts frequently occur slightly or not at all stained. The stain I use is borax carmine and nigrosine, followed by treatment with acid alcohol for differentiation, so that the parasite is possibly more readily decolourised than the fungus. When well-stained the excrementitious mass is often even darker than the nucleus, which still retains the characteristic rhizopod type. From comparison of successive stages (Figs. 9–13) in stained preparations we find that the nucleus then undergoes complete bipartition to form from four to sixteen—usually eight—daughter nuclei; which soon become regularly distributed through the protoplasm. The latter then divides according to one of two ways: either the vacuole around the fæcal mass sends directly radiating processes outwards, or else radiating vacuoles appear in the plasma and open first into that surrounding the fæcal mass before they extend to the periphery, and so divide the plasma into wedge-shaped masses. These are the zoospores. One of these bores through the cyst-wall, and the others follow through the same hole; no discharging process is formed as in Chytridieae and Saprolegnieae themselves. The zoocyst-wall persists; but the excrementitious mass left within soon disintegrates and disappears (Figs. 14, 15). Hyphae attacked by *Woronina polycystis*, may also be attacked by our parasite, which lives

and forms its zoocyst unaffected by the presence of the Chytridian.

As stated above, the species I have described differs little so far from Cienkowski's type *P. parasitica*; and I should not have ventured to separate it but for one reason: the type-species preys on Desmids and Conjugates; ours never attacks green Algae (nor Phycochromaceae) unless they be previously injured: this point I have made out by observation.

As to its systematic position. Following Cienkowski and Zopf, this must belong to the Monadineae Zoosporeae, possessing mastigopod zoospores. This is divided by Zopf into three orders: Plasmodiophoraceae, Gymnococcaceae, and Pseudosporaceae. In the absence of resting-spores we can only affirm certainly that it does not belong to the first; but from its extreme likeness to *Pseudospora parasitica* C. it is almost certainly a member of the same order and probably the same genus. I define it thus:

'*Pseudospora* (?) *Lindstedtii* mihi. Monadinea Zoosporea, zoosporis oblongatis 1–3 flagellatis, postea Heliozoi habitu nec in plasmodia coalitis; Zoocystis massâ faecali excentricâ vacuolo spherico circumdatâ praeditis, 4–16 (plerumque 8–) paris; in hyphis Saprolegniearum diversarum (*Leptomiti*, *Saprolegniae*, *Achlyae*), nec in algis viridis v. cyaneis parasitica; sporis "quiescentibus" dictis adhuc ignotis.'

We may now revert to the position it has taken in the Saprolegnia-fertilisation controversy.

Pringsheim, as mentioned above, states that certain portions of the antheridial protoplasm of Saprolegnieae become specialised and escape as spermamoebae to fertilize the oospheres. Zopf in a series of theses gives the following account. Numerous minute amoebae appear in the antheridium of Saprolegnieae at the time of fertilization, pass into the antheridial tubes and apparently disappear on arriving at the oospheres. The oospore shows however changes due to the infesting parasite, manifested in the appearance of numerous fat-globules finally coalescing into a single lateral drop. The protoplasm and wall of the oospore thus affected show

changes indicating its 'pseudomorphism' into a parasite-spore. Besides these, *other parasitic swarmers are found which become somewhat amoeboid* ('schwach amöboid werden') *and bore into the vegetative hyphae; these are larger than the former and possess a pale nucleus.* They may enter the antheridium and pass down the fertilizing tubes into the oogonium, and according to Zopf form zoocysts therein, but do not prey on the spores. The smaller amoebae, and to some extent the larger, he regards as identical with Pringsheim's spermamoebae. Now while it is obvious that in many respects Zopf's larger amoebae correspond with my species, he refers them in his monograph to the genus *Vampyrellidium*[1], and species *V. vorax* Z., which differs in that the zoospores do not pass through a mastigopod stage, and, from his figures (Fig. 37), in the characters of the zoocyst which has granular peripheral plasma, with a central nucleus surrounded by hyaloplasma; and finally in preying on green Algae as well as on Saprolegnieae. This species I have not found; but I cannot help thinking that he must have overlooked the differences between it and mine, which is unmistakably that figured by Pringsheim and recognised by Lindstedt, and which I have never found absent from old cultures. While in his paper he says they do not attack the oospores, in his monograph he says they wander 'in die vegetativen Schläuche sowohl als in die Oogonien und Antheridien hinein, nähren sich vom Inhalt dieser Organe, und bilden in ihnen schliesslich auch Dauersporen.' I have repeatedly seen my organisms destroy the young oospores before encysting in the oogonium, so that the same oogonium may contain zoocysts of the parasite and oospores of the Fungus; and they sometimes even attack the ripe oospores despite the protection of the thick cell-wall. I think it very possible that Zopf may have confused two species here. His phrase 'Schwärmer, welche schwach amöboid werden' would seem to imply that they were previously flagellate, and hence could not belong to *Vampyrellidium.*

[1] Die Pilzthiere oder Schleimpilze, 101.

Pringsheim in his reply denies that the large amoebae can have anything to do with his spermamoebae. He admits that amoebae may be seen in empty organs which are no longer closed, and that Chytrideae and their allies can, of course, in the swarming stage penetrate healthy normal organs, but observes, justly, that these have nothing to do with Zopf's amoebae. He denies that the amoebae so often seen crawling over the hyphae ever penetrate them, and refers Zopf's observations to a confusion with the cellulin-corpuscles, which by the way I may note he was the first to correctly describe and name in a full study in a later paper[1]. His words are worth quoting: 'Es sind frei im Zellumen der Saprolegnieen-Schläuche und in den Oogonien niedergeschlagene und im Alter geschichtete Körner aus einer Art Pilzcellulose, oder eine verwandte Modification derselben. . . . Es sind diese körnige Niederschläge des Zellinhalts, welche derselbe [Zopf] für zu Ruhe gekommene Amöben und Spermamöben angesehen hat.' On this identification I may note that it is obviously wrong, as the cellulin-granules always disappear in the formation of spores, and it is only in hyphae emptied by the action of parasites that I have ever found them persist. Pringsheim's own old figure of *Leptomitus* with a zoocyst of the Monadine side by side with a laminated cellulin-body, is ample proof of the inaccuracy of the last conclusion. I have frequently seen an amoeboid of the form of an acute isosceles triangle, with the angles rounded and the base anterior in locomotion ('*Amoeba limax*' form), crawling about my cultures; but this is quite distinct from the amoeboids of any monadine[2].

It is strange to find that Pringsheim should have fallen into this confusion, and that neither he nor possibly Zopf appears to have seen the mastigopod stage. I can only account for it by the hour at which swarming takes place, an hour not likely

[1] Berichte d. Deutsch. Bot. Gesellschaft, 1883.

[2] Pringsheim also answered Zopf in a paper in his own Jahrbücher (vol. xiv. 1884, p. 111, Nachträgliche Bemerkungen z. d. Befruchtungsact von *Achlya*), but he gives no further account of the larger amoebae which alone concern us here, nor does he even refer to his previous reply to Zopf in the Centralblatt.

to be chosen by a man who has leisure for original research in the daytime.

It is obvious that, as my organism is probably identical with Zopf's larger amoebae, while his smaller ones are equivalent to Pringsheim's spermamoebae, the foregoing study does not directly solve the question as to the fertilization or apogamy of the Saprolegnieae. Yet in so far as it proves that Pringsheim has confused a parasitic with a normal structure in the one case, it raises a presumption that he may have made the same mistake in the other; and I have a strong body of evidence from a totally different source tending to prove that his theory is erroneous. But this belongs of right to my nearly completed study of the protoplasmic structures of the Saprolegnieae and will be fully discussed therein.

EXPLANATION OF FIGURES IN PLATE XXII. B.

Illustrating Prof. Hartog's paper on a Monadine parasitic on Saprolegnieae.

Figs. 1, 2 (× 750 E). Two young swarmers as drawn in the infested hyphae which contains also mature zoocysts; nucleus seen.

Fig. 3 (× 750 E). Young amoeboids in the living hyphae of *Achyla*. Two contractile vacuoles shown, one in the moment of reconstitution after systole by the confluence of three minute ones. *n* = nucleus; *co* = contractile vacuoles.

Figs. 4, 5, 6 (× 750 E). Older amoeboids from within a hypha; 5 and 6 are successive stages of the same; a few bright (faecal?) granules present.

Figs. 7, 8 (× 750 E). A migrating amoeboid inserting a pseudopodium into a living hypha; two successive stages.

Figs. 9–13 (2 mm. apochr., 12 Comp. Oc. × 1000; owing to their being balsam specimens this is equivalent to a magnification of 666 × the living organism). 9, young zoocyst with faecal mass (*e*) and nucleus; 10, same, with seven daughter nuclei visible (eight in all); 11, 12, further stages of spore-formation, the spore-origins somewhat unduly separated by shrinkage; 13, the spores completely separated.

Fig. 14 (same magnification). Balsam specimen at commencement of zoocyst-formation, with flagellum protruded.

Fig. 15 (× 750 E). Same stage living; some of the faecal granules still in the protoplasm.

Fig. 16 (× 750 E). Live zoocyst, divided partially into spore-origins by radiating vacuoles.

Fig. 17 (× 350 E). Portion of infested hypha of *Achyla* with zoocysts and cellulin-bodies (*c*).

Besides the magnifications, the objective of Zeiss under which the drawing was made is given.

On antithetic as distinct from homologous Alternation of Generations in Plants.

BY

F. O. BOWER, D.Sc.,

Regius Professor of Botany in the University of Glasgow.

THERE are few subjects within the scope of Biology which have given rise to so much divergence of opinion, and at the same time so great obscurity of conception as that of 'alternation of generations.' For more than half a century the fact that within the narrow limit of the ontogenetic cycle, like does not always directly produce like, has been known and discussed, the discussion most frequently taking the form of mere comparison of the successive phases of various organisms, with but slight reference, if any, to the external circumstances under which the organisms grow, or to their relationships by descent. At the present time, knowing as we do how profoundly the environment affects the conformation of the organism, it is imperative that in the discussion of the phenomena of alternation such considerations should be constantly kept in mind, and especially the differences of external conditions of the organisms in which alternation is seen.

Before the days of the theory of evolution, when the idea of uniformity of type in organic creation held stronger sway over the minds of biologists than now, it was natural that the attempt should be made, by coercing facts into correspondence, to draw comparisons where they are not warranted: even among those who accept evolutionary views, the tendency

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remains—perhaps in order to simplify matters—to regard as homologous and truly comparable all such similar forms and phases as have not been actually demonstrated to be diverse in origin or nature. So with the study of alternation of generations; this term, the very sound of which has an insidious attractiveness, has been commonly used in a very extended sense, and applied with little discrimination to the succession of phases of life of different organisms, whether these be truly similar to, or dissimilar from, one another; and thus there has grown up the idea that an alternation of generations is due to some quality inherent in many organisms, and especially in plants, which leads them to pass through certain definite phases in the progress of their individual life. Such a view was at least implied by Sachs when he said[1] that the doctrine of alternation has the object of reducing to one scheme the main phases of life of all plants which bear sexual organs; such an object involves the presumption of a much greater uniformity of organic nature than can be justified by known facts. We must rather be prepared to find and to recognise in our classification of such phenomena various results of the impress of different external conditions upon diverse organisms, and avoid, rather than press forward, the reduction of phases of life of all organisms which show sexuality to one rigid scheme.

I am convinced that a merely formal comparison of different organisms, or of their successive stages one with another, will not suffice for the solution of the question as to the real nature of alternation. In order to gain a true conception of the meaning of alternation as a wide-spread biological phenomenon, the question should be approached from the physiological rather than the purely morphological point of view, while the conclusions thus arrived at are to be checked in accordance with what is known of phylogeny[2].

[1] Lehrbuch, 4th ed. p. 234.

[2] It will be unnecessary to quote and compare the diverse views of different writers on the subject of alternation: it will rather be my object to state briefly my own opinion, comparing it incidentally with those of others, where strong divergence exists.

Taking first, as the most prominent example, the Fern, we shall enquire what is the meaning of the alternation as we see it there. The gametophyte or prothallus of Ferns shows in its more delicate structure and its habit, as well as in the way in which the sexual process is effected, an adaptation to moist conditions, under which it grows best, while its ultimate function, that of sexual reproduction, cannot be carried out without the presence of external fluid water: it is, in fact, typically semi-aquatic in its nature, sharing its main characters with the Algae from which we have every reason to believe that the land-flora originated. The sporophyte, on the other hand, is fitted by its more robust texture as well as by its differentiation of tissues for successfully enduring exposure to the air under comparatively dry circumstances, while dry weather is important for the dispersal of the spores which it is the final function of the sporophyte to produce: thus the Fern, as we normally see it, is an organism with, so to speak, one foot in the water, the other on land.

Calling in also such evidence from phylogeny as we can command, it will, I think, be generally accepted that the gametophyte is the older and pre-existent generation[1]; it corresponds to the gametophyte as seen in the Liverworts, or in the green Algae, and if we trace the descent of the great archegoniate series from some green Algal forms, we may recognise that the gametophyte of the Ferns retains the chief Algal characters, as regards both its texture and its sexual process. The sporophyte, on the other hand, is the younger generation: among the present green Algae, which must undoubtedly have been in some measure related to the progenitors of the Archegoniatae, there is hardly any body strictly comparable to the sporophyte, nor is it to be expected that there should be, if as above stated the sporophyte is typically sub-aerial in its characters, while the green Algae are typically aquatic. A comparison of the successive families of the archegoniate series demonstrates

[1] This view was definitely stated by A. Braun, Ber. d. k. Akad. zu Berlin, 1875, p. 297.

the progress of the sporophyte from small beginnings in the lower Bryophytes to large size and great complexity of form and structure in the Vascular Cryptogams and Gymnosperms; its advance is accompanied by a corresponding reduction of the oophyte, and the whole is to be correlated with a progression from the aquatic or semi-aquatic habit of the lower forms, to the very distinctly sub-aerial habit of the higher. Taking all these points into our general view, it may be concluded that the alternation which is so prominent in the main archegoniate series is the result of adaptation of originally aquatic organisms to sub-aerial conditions of life: it may, in fact, be distinguished physiologically as an *amphibious alternation*, which finds its morphological expression in the difference of external form and internal structure between the more ancient gametophyte and the more recent sporophyte.

Regarding the archegoniate series from the point of view of descent, it is seen that the alternation must have been the result of *interpolation* of a new development between successive gametophytes, an intercalation of a new stage more especially adapted to life in air rather than in water —that intercalated stage being what we recognise as the sporophyte: this being so it is no matter for surprise that it should usually differ from the gametophyte in external form, though it may at times simulate it to a greater or less degree. Accordingly this alternation in the archegoniate series may from the phylogenetic point of view be styled an *alternation by interpolation* of a new sub-aerial phase between the pre-existent semi-aquatic ones: or, if the introduction of new terms be thought undesirable, this alternation may be called after Celakovsky[1] an *antithetic alternation*.

It is a direct outcome of this view of the origin of the sporophyte by interpolation of a new phase, which edged its way in, so to speak, between successive gametophytes, that it cannot itself be a gametophyte which has undergone a

[1] Sitz. d. Ges. d. Wiss. in Prag, 1874, p. 30.

change of form: this latter view has however found acceptance with more than one writer: Strasburger[1] and Pringsheim[2] both contemplated the possibility of the sporophyte having originated as a modification of a gametophyte: thus Strasburger wrote as follows[3]: 'For all plants from the Mosses upwards it appears to me probable that we have to do merely with a differentiation of a single original generation, that is with a Strophogenesis, and that if a developmental cycle consists of more than one independent, living, i. e. physiological, individual (according to Haeckel's definition), these individuals owe their origin only to individualisation of certain members of a single generation'; while Pringsheim wrote[4]: 'The alternation of generations of the Mosses appears accordingly as a contracted form of the alternation of generations of the Thallophytes, in which the neutral generations are reduced to one, and this one remains in inseparable connection with the sexual.—The great apparent difference in habit of the Moss sporogonium and the Moss plant thus reduces itself to the feeble development of the vegetative part, i. e. the axis, which is connected with the early formation of the sporangium upon it.—In the true Mosses in which the axis (of the sporangium) is less feebly developed than in the Liverworts, the identity between it and the Moss stem is expressed even in the anatomical structure.' This identity Professor Pringsheim considers to be demonstrated by the production of protonemal filaments from the seta itself (apospory), and he suggests it as not improbable that teratological conditions of the Moss sporogonium may be found bearing rudimentary leaves. Here there is propounded a view which is entirely at issue with that above stated; but the support of it appears to me to amount to little more than mere surmise or to be based upon the facts of apospory, a rare phenomenon which we have every reason to regard as teratological: against it has to be placed the whole weight of evidence of descent of the arche-

[1] Jenaische Zeitschr., 1874, p. 69. [2] Pringsh., Jahrb., Bd. IX. p. 43, 1878.
[3] l. c., p. 69. [4] l. c., p. 43.

goniate series, in which the progress of the sporophyte from a minute, indifferentiated body to the large independent plant may be followed; and though the evidence concerning the evolution of the Archegoniatae must naturally fall short of actual demonstration, it is at least sufficiently satisfactory to substantiate the view that the sporophyte is a result of interpolation of a new stage between successive gametophytes, rather than a result of formal modification of the gametophyte itself[1].

Accordingly it may be concluded that in the first and most prominent case of alternation of generations (that in fact which is recognised by botanists as *par excellence* the typical alternation) the origin of the alternation may be correlated with a change of habit from aquatic to sub-aerial life, and the neutral generation or sporophyte may on phylogenetic grounds be viewed as an interpolation of a new, and essentially sub-aerial phase between successive gametophytes: we will next enquire whether any other type of alternation, differing in nature or in origin, occurs among other plants.

On this point we find in the Text-book of Sachs[2] a direct expression of opinion: it is there stated that a comparison of the development of the Thallophytes with that of the Muscineae and Vascular plants will show 'that the development of all plants which possess sexual organs may be divided into two stages which correspond in all essential points to the two generations in the life-history of a Fern: and that there is, therefore, in the whole vegetable kingdom only one type of alternation of generations so far as it is brought about by sexual organs.' In his later published Lectures Professor Sachs does not materially alter this opinion. In the same year as the above passage was published, Celakovsky had however given an address[3] on alternation, which states very clearly the reasons for his drawing a distinction between different types of alternation; the chief point which he there insisted

[1] This view is clearly stated by Naegeli, Abstammungslehre, pp. 474, 475.

[2] Second English Edition, p. 229, or fourth German Edition, p. 234.

[3] Sitz. d. k. Böhm. Ges. d. Wiss., March 6, 1874.

upon was subsequently accepted by Alexander Braun[1]: but his views, which will now be considered afresh, were as regards the majority of European botanists completely overshadowed by the authoritative dictum of Sachs: while we recognise the great merits of the Text-book which ensured to it a cosmopolitan circulation, it is nevertheless to be remarked that the almost dogmatic attitude, which the author adopted with regard to alternation of generations, has prevented the spread of Celakovsky's views in quarters where their merits should have ensured acceptance.

Putting on one side the subject of 'alternation of shoots' to which Celakovsky devoted much attention, and which is suitably referred to by Sachs[2] as a phenomenon of minor importance, we recognise as the great contribution which Celakovsky made to this subject, that he drew a broad distinction between *antithetic alternation*, and *homologous alternation*[3]. The former term he applied to that alternation which is seen in the archegoniate series: he clearly recognised that in the archegoniate series the sexual was pre-existent from the point of view of descent, and called it the 'Protophyt,' while the neutral he styled the 'Antiphyt': it is unnecessary for us to adopt these terms, as the words gametophyte and sporophyte are suitable and firmly established. The term *homologous alternation* was applied by Celakovsky to that type of alternation which, though a much less clearly defined phenomenon, commonly occurs in the Thallophytes, and the term implies the basis of distinction between this and antithetic alternation[4]: it consists in a differentiation *inter se* of homo-

[1] Sitz. d. k. Akad. zu Berlin, 1876, pp. 289, &c.

[2] Text-book, 2nd Eng. Ed. p. 228, last paragraph. [3] l. c., p. 30.

[4] There will doubtless be found some botanists who will object to these phenomena being included in the term alternation; I think however that it is desirable that they should be, for two reasons: first, because the original use of the term as applied to animals covered and indeed referred chiefly to such phenomena as these, the antithetic alternation finding no counterpart at all in the animal kingdom:—this has been pointed out by A. Braun (l. c., p. 296); and secondly, because I think it is desirable, even at the risk of less simplicity of classification, to accentuate the difference between the antithetic alternation, and those phenomena in the lower plants and in animals, to which the term alternation was first applied by Steenstrup. Botanists are apt to lose sight of the original use of the term alterna-

logous generations which are fundamentally alike as regards descent; the differentiation may be simply as regards the character of the reproductive organs which they bear, or there may also be a differentiation of them as regards form, which, though clearly seen in some animals (e.g. the Medusae), is among plants of more rare occurrence. As in the case of antithetic alternation, so also may the homologous alternation be correlated with changes of external condition, and in some of the more protean forms the interdependence would appear to come out clearly: a series of examples will now be discussed by way of illustration of what is meant by homologous as distinct from antithetic alternation.

Taking first the Siphoneae, this protean family will prove most instructive. Though not the simplest of these plants in its sexual process, *Vaucheria* has a comparatively straightforward life-history: the zygote after a resting period germinates directly into a new *Vaucheria* plant, which may reproduce itself by brood-cells throughout a series of generations, which are similar to one another: finally on plants resembling these in every respect except in the reproductive organs which they bear, the oogonia and antheridia are produced and fresh zygotes formed. Now here is a series of generations similar in all essentials except one: there is no reason to regard them as showing a true or antithetic alternation, but they should all be recognised as potential gametophytes[1], a differentiation of them *inter se* having taken place to the extent that some produce only brood-cells, others sexual organs: in a similar manner the gametophyte of a *Marchantia* or *Tetraphis* may for a series of generations reproduce itself by gemmae (gametophytic budding) and the last generation bear sexual organs. If we are to recognise the sporophyte at all, it is in *Vaucheria* represented only by the zygote:

tion, in view of the more striking phenomena of antithetic alternation in plants, while on the other hand Zoologists are apt to regard the latter as on a par with alternation in animals. Both these dangers are avoided by retaining the words in their original sense. Compare De Bary, Fungi, p. 125.

[1] 'Potential oophores' is a term applied to the corresponding generations of *Colcochaete* by Vines, Lectures on Physiology, p. 632.

thus inasmuch as there is a differentiation as regards the mode of reproduction, we may in a sense distinguish an alternation of generations; but since such generations are similar to one another in every other respect, they are all to be considered as potential gametophytes, and homologous one with another: *Vaucheria* may thus be taken as a simple example of ***homologous alternation*** of non-sexual and sexual gametophytes.

In addition to the above phases of life a resting stage has also been described by Stahl[1], the *Gongrosira* stage, which appears to result from conditions of drought: the separate protoplasmic masses, produced by fragmentation, are each surrounded by a gelatinous cell-wall, and may undergo a period of rest: they germinate on exposure to suitable conditions, either by direct formation of new *Vaucheria* tubes, or by division of the protoplasmic body, and escape of the portions as separate amoeboid bodies, which ultimately develope into new *Vaucheria* tubes. Here is a peculiar adaptation to peculiar circumstances, but there is no reason to see in it more than a variant upon the structure of the ordinary gametophyte, and it may be ranked with other developments of the gametophyte. If the *Gongrosira* form be dignified by being styled an alternate generation, it is simply a generation homologous with the gametophyte.

If we compare other examples of the Siphoneae, even where an alternation has been recognised by others, it will be seen that it is nothing more than an ***homologous alternation***: thus in *Botrydium*, in which Rostafinski and Woronin have described such various forms of reproduction[2], the life-history, though complicated, falls into the same plan. The gametes (here similar to one another) after conjugation form the resting zygote, which corresponds to the zygote of *Vaucheria*: this on germination, as in *Vaucheria*, produces the vegetative *Botrydium* plant. Under divers circumstances this may reproduce itself vegetatively in very different ways: by the formation of swarm-spores, which may be produced in four

[1] Bot. Zeit., 1879, p. 129.

[2] Bot. Zeit., 1877, pp. 663, &c.

different ways, or by fragmentation of the protoplasmic contents, these rounding off and forming cell-walls round each of the portions. In the formation of the swarm-spores the processes are essentially similar in nature, though different in detail, from those in *Vaucheria*, while in the various forms of resting spores, and even in those spores from which the gametes are derived, I think we see developments more or less closely comparable to the *Gongrosira* stage of *Vaucheria*. They may all be placed in the category of adaptations of the gametophyte itself to external circumstances, and at best we have here only an alternation of adaptive stages resulting from the differentiation of generations, *homologous with one another*—all being potential gametophytes. But Rostafinski and Woronin took a different view[1]: they styled the vegetative plant a 'sporophore generation,' while the 'oophore' is represented by the sexual gametes which form the zygote, this being itself the limit of the two generations[2]. Comparing *Botrydium* with other Chlorosporeae they say that '*Botrydium* affords us an alternation of generations in which the existence of the vegetative plant falls in the post-embryonal period of life, as in the Ferns. In all other Chlorosporeae it is otherwise, as in the Moss; the vegetative plant arises from the spore, not from the ovum.' Hence we are to conclude that within the natural family of the Siphoneae the *Vaucheria* plant is the gametophyte, and the *Botrydium* plant the sporophyte, the comparison being strengthened by allusions to the Ferns and Mosses! I have chosen this example because it brings out very clearly the fundamental fallacy which underlies such a comparison: the term spore is by these authors applied to certain round bodies produced within the *Botrydium* plant under certain circumstances: it is assumed that, because they are round, limited by a cell-wall, and that from them the gametes are derived, therefore they are comparable to the spores of the Mosses or Ferns. But why should there be anything in the life-history of Botrydium strictly comparable to the spore of the Moss or Fern? It is exactly this assump-

[1] l. c., p. 666. [2] l. c., p. 663.

tion that there is, which underlies much of the misconception regarding alternation, and it comes out incidentally in the paper above quoted that this assumption is made: after stating that these spores of *Botrydium* close the first or sporophore generation, while the zygote is the second limit between the two generations, the authors remark, 'Alles Uebrige sind Anpassungs-Erscheinungen': '*All other phenomena are phenomena of adaptation.*' Are then sexuality and spore-formation not phenomena of adaptation? Are both the stages, like the laws of the Medes and Persians, fixed and unalterable for all time and in all plants?—most certainly not. It is found convenient and for the present reasonable to assume that sexuality is a uniform process throughout such organisms as show it, and the result of sexuality, the *zygote*, may therefore be assumed to be homologous in different forms, and be taken as a fixed comparable point in their life-cycle. For purposes of clearness of comparison, if not on other grounds also, this will I think be generally conceded. Are we justified in assigning a similar fixed position and general homology to the spore? When a comparison is made of the archegoniate series, the stage of spore-formation is found (with certain rare exceptions) to recur constantly, and for that particular series, on phylogenetic grounds as above stated, the recognition of spores as homologous is perfectly justified; even there however the formation of spores is to be regarded as a phenomenon of adaptation fixed by heredity, so that it recurs as a constant period in the antithetic alternation. But the question is whether this fixed character of the sporal stage is also to be found constantly in the Thallophytes. Those who, like Rostafinski and Woronin[1], draw close comparisons between alternation in *Botrydium*, and that in Mosses or Ferns, assume that it is: to my mind, there is abundant evidence, even within the Siphoneae, to show that it is not: the mere fact of the presence of these 'spores' in *Botrydium*, and their absence in the sexually higher

[1] l. c., p. 664. The authors have pointed out in the most interesting way the dependence of the several stages upon external conditions.

Vaucheria, shows their inconstancy, and if the 'spores' are of inconstant occurrence within the *Siphoneae*, how can we draw secure comparisons between those which are only occasionally present in the Siphoneae and those in the remotely distant Mosses and Ferns? Accordingly the sporal stage comparable to that in Mosses or Ferns must be abandoned as a fixed point in the life-cycle of such Thallophytes as *Botrydium, and the zygote alone remains as a point of fixed homology for comparative purposes*[1]. It follows necessarily that the tracing of an alternation comparable to that of the Archegoniatae in such a plant as *Botrydium* is a mere mental fiction. Such alternation as there is appears in this plant to be very directly dependent upon external conditions, and is to be recognised as a complicated form of alternation of homologous gametophytes, brought about by repeated and varied gametophytic budding. What has now been said of *Botrydium* will apply in all essential points equally well to *Acetabularia*.

Other groups of Algae also display phenomena comparable to these: but it will, I think, be unnecessary to follow the similar lines of reasoning out for all the main groups: it will suffice to remark that gametophytic budding appears to be absent, or at least rare, in certain cases (e.g. *Fucus*), but it is usually present; thus in *Oedogonium* and *Coleochaete* swarm-spores are formed, in *Volvox* the special cells of the coenobium which give rise to new coenobia, in Florideae the tetraspores, &c.: in all these cases the vegetative reproduction is a gametophytic budding, and such alternation as occurs *is an alternation of homologous generations*, which may frequently be correlated directly with season, or other external circumstances.

Turning to the Fungi, similar reasons to those above stated in the case of certain Algae may be found for recognising in them an alternation of homologous generations, derived one from another by a propagative process which may be styled gametophytic budding: reference will be made to certain

[1] Compare De Bary, Fungi, Eng. Ed., p. 121.

examples. *Mucor* has frequently been referred to as showing an alternation, and it has been pointed out how from the zygospore one or more thick hyphal tubes are formed, which are non-sexual, and at once form gonidiophores; that the mycelia derived from these gonidia may again propagate by gonidia, until finally a formation of zygospores may take place. In such a life-cycle an homologous alternation of potential gametophytes[1] is to be seen, similar in its main aspects to that in *Vaucheria*, the gonidia being examples of gametophytic budding, not a true spore-formation such as that in Ferns or Mosses. It is further to be noted in support of this that while in *Mucor* the hyphae which germinate from the zygospore are non-sexual, in *Sporodinia* they may directly produce fresh zygospores[2].

Brefeld[3] has discussed the dependence of the Mucorini, as also of Fungi at large, upon changes of external condition, as regards the formation of sexual and non-sexual organs of reproduction: he has pointed out that where sexual and non-sexual modes of reproduction occur on the same individual, external conditions may take part in determining the preponderance of the one or the other: starving may encourage sexuality, while high feeding encourages non-sexual reproduction; but he points out that in certain forms sexuality has so far fallen into abeyance, that suitable external conditions are insufficient to induce it with certainty; but this point, which is applicable for large families of Fungi (and, as he shows, to the Mucorini themselves), need not interfere with the general conclusion that in these organisms also the alternating modes of reproduction are to be viewed as originally the outcome of alternating external conditions, and not as in any sense absolutely fixed stages. Other reasons may have supervened to make one stage or the other more prominent in the life-cycle of a given species or family[4], or even lead to

[1] Vines' Lectures, p. 634.

[2] Schimmelpilze, Heft IV, 1881, p. 74.

[3] De Bary, Fungi, p. 147.

[4] With regard to the abeyance of sexuality in Fungi, compare Marshall Ward, Q. J. M. S., 1884, pp. 305, &c.

complete suppression; but still there is sufficient closeness of sequence between changes of external condition and modes of propagation in such a group as the *Mucorini* to justify the above conclusion. Similarly in the case of other Fungi, accepting the homologies indicated by De Bary[1], into the details of which it is unnecessary at present to enter, those reproductive cells which he has styled gonidia are collectively to be viewed as mere vegetative amplifications of the life-cycle, and comparable to that gametophytic budding, which has been so styled in the Algae, and also in the Mosses and Ferns. Further, the comprehensive view given by De Bary of the occurrence or non-occurrence of such budding within certain families[2] falls in with the corresponding irregularity of its occurrence in the Archegoniatae, and in the Algae.

It has now been pointed out that an antithetic alternation such as that in the archegoniate series is absent from the life-cycle of certain Algae and Fungi, in which the attempt has been made by some writers to trace it: the further question remains whether or not there is an antithetic alternation in any of the Thallophytes. Taking first the green Algae, well-known cases of formation of the fruit body with spores, or rather *carpospores* in the sense of De Bary[3], have long been recognised in *Oedogonium* and *Coleochaete* and probably also in *Ulothrix*, &c., and in a minor degree in some Desmids: here the zygote, instead of remaining undivided, and germinating directly into a new oophyte, undergoes a process of segmentation to form two, four, or more *carpospores* each of which may grow into a new individual gametophyte. As regards their origin and their position in the life-cycle, these correspond to the true spores (or carpospores) of the Liverwort, or Moss, or Fern; but there the similarity ends, for they differ in the circumstances under which they are formed, as well as in the bodies immediately produced from them, which are in the one case motile, in the other fixed. I should be disposed, therefore, while classifying these spores as *carpospores* in

[1] Fungi, Eng. Ed., p. 223. [2] Fungi, pp. 224, 337, &c.
[3] Fungi, p. 129.

De Bary's sense, not to regard them as phylogenetically identical with those of the archegoniate series, but rather as a parallel development—a similar response to a somewhat similar stress of circumstances: the rationale of formation of carpospores is the multiplication of the species without a corresponding repetition of the sexual process, in fact an economy of sexuality together with a uniform distribution of the effect of the sexual process: this may doubtless have been of importance both in the Archegoniatae and in the green filamentous Algae, and it is reasonable to think that both series may have developed in a somewhat similar direction, though by a distinct evolutionary sequence.

The same line of reasoning will also apply to the case of the Florideae, which are undoubtedly less closely allied to the Archegoniatae than are the Confervoideae: in these there is a more obvious interpolation of an intermediate growth between the successive gametophytes. The gametophytes may reproduce their like by tetraspores (gametophytic budding), which are often borne on distinct sexual plants; ultimately, as the result of fertilization of the procarps (borne often on distinct sexual plants), a growth of a more or less extensive nature is produced either from the actual cell fertilized (*Nemalion*, *Batrachospermum*), or from an adjoining cell or cells of the procarp (*Lejolisia*, &c.), or even more indirectly, from adjoining procarps to which the fertilizing effect is handed on (*Corallina*, *Dudresnaya*, &c.), and this results in the formation of carpospores. We may allow the use of this term, and recognise in the carpospores the result of a growth succeeding a sexual act, and differing in form and mode of production from the tetraspores: a comparison of different members of the Florideae will also suggest how such developments may have resulted from an interpolation of a developmental stage in a manner to some degree comparable to the interpolation of the sporophyte in the archegoniate series.

It is hardly necessary to point out that much the same is the case for the Ascomycetous Fungi, and that the series of ascogenous hyphae (e. g. in *Ascobolus* or *Eurotium*), upon

which the asci and ascospores are produced, may be regarded as an interpolated stage in the life-cycle; but all these examples might probably be classed with greater propriety as instances of analogy, than of strict phylogenetic homology.

Having recognised that though analogies as regards alternation are to be found between certain Thallophytes and the Archegoniatae, the identity is not a close one, we may now return to the consideration of the main archegoniate series of Plants: as above noted it is an important fact that in them the antithetic alternation is constant, though the balance of the two generations may vary: the very constancy of the phenomenon makes us enquire why it should be so: the circumstances which have led to this constancy seem to me to have been these. The archegoniate series is undoubtedly of Algal origin, and this their gametophytes amply bear out: they probably sprang from filamentous green aquatic forms, inhabiting, as so many of the green Algae now do, shallow fresh water, or the higher levels between the marine tide-marks[1]: the sexual reproduction was effected through the means of external water, and if other conditions were favourable it could be effected at any time through the water which was always present. Certain forms, perhaps thereby escaping from competition, spread to the land, where access of water was only an occasional occurrence: in these the sexual process could only be effected at time of rains or floods, or copious dews, and even then might not take place unless the sexual organs were fully mature: thus less dependence could be placed upon sexuality for propagation, and an alternative method of increase of individuals had to be substituted. This was done by the production of the sporophyte from the zygote: once fertilized a zygote might in these plants divide up into a number of portions (carpospores) each of which would then serve as a starting-point of a new individual, and dry circumstances, under which they would be powdery, would favour their dispersion, as in the lower Liverworts. In proportion as these plants spread to higher and drier levels

[1] Compare Weissmann's statement that 'the birthplace of all animal and plant life lay in the sea.' Nature, 1882, p. 564.

(in accordance with the advantage which they gained from escape from competition, and more free exposure to light for assimilation) the chance of a frequent recurrence of the circumstances necessary for sexual reproduction would be diminished, and the dependence upon carpospores for propagation would increase: consequently the number of spores produced by each sexually formed sporophyte must be larger, if the race is to survive, and be in a position to compete. Any increase in the number of spores entails greater supply of external nourishment during their formation; this in the phylum of the Bryophytes is chiefly supplied from the gametophyte, which shows distinct adaptation to sub-aerial habit, while the means of nutrition on the part of the sporophyte itself are in these plants very limited, and the external morphological complexity of it very slight. In other distinct phyla, however, such as the Filicinae, Lycopodinae, and Equisetinae, the sporophyte itself assumed the function of nutrition: a higher morphological differentiation of parts followed, and a more clear distinction between the organs which were to supply the nutriment (stem, leaves, roots) and the parts devoted to the formation of spores (sporangia): this for the first time stamped the sporophyte with a character of independence and permanence, while the number of spores produced might now be practically unlimited: in these respects the Vascular Cryptogams are immeasurably superior to the Bryophytes. One strange point in the whole story is, however, the tenacity with which these plants (under the obvious disadvantages which it entails when their habit is sub-aerial) retained their aquatic type of fertilization; it is only when we reach the Phanerogams, where the sporophyte reaches its climax while the gametophyte is almost abortive, that we see the sexual process accommodated to that sub-aerial life which had led to the dominant position of the sporophyte; for in them the fertilization is siphonogamic, being carried on by the pollen tube: these plants are therefore independent of external fluid water for their fertilization, and this fact has doubtless contributed largely to their present

ascendency. When, as in the preceding sketch, we consider what the results of the migration from water to land must have been, the permanence and constancy of the antithetic alternation explains itself. The permanence or morphological fixity of a phenomenon in any phylum is in a sense proportional to its importance in the well-being of the organisms: given a conservatism in the mode of fertilization (which I confess is difficult to explain), the rise and progress of the sporophyte in the archegoniate series, and the constant recurrence of the antithetic alternation, appear to me to be a natural outcome of the migration from water to land[1].

It is much more difficult in the Florideae and Ascomycetous Fungi to recognise or suggest what circumstances may have led to the interpolation of the neutral phase in their life-cycle: it is out of the question that the conditions have been the same as those which, according to the above view, conduced to the antithetic alternation in the Archegoniatae: while we recognise the chief determining conditions for these, the absence of such in the case of the Florideae and Fungi would be an additional reason for not considering the interpolated phase in them as strictly comparable to that in the Arche-

[1] Professor Geddes, in his recent work on the 'Evolution of Sex,' writes concerning the rationale of alternation as follows (p. 214):—

'A survey, in fact, of the conditions and characteristics of the two sets of forms, inevitably leads us to regard the asexual generation as the expression of predominant anabolism, and the sexual is equally emphatically katabolic. Alternation of generations is, in fine, a rhythm between a relatively anabolic and katabolic preponderance.'

I leave zoologists to deal with this generalisation from the zoological point of view; as applied to plants I dissent from it entirely. If we regard only the Fern, I will admit that the prothallus is *smaller* than the Fern-plant, and that the two follow one another in alternate succession; if this be all that is meant by the turgid phrase 'a rhythm between a relatively anabolic and katabolic preponderance,' the above quotation may in a sense be accepted as applicable to *Ferns*. But how is the above statement to be applied in the case of the Moss or Liverwort? It is obviously absurd to say that the large green assimilating gametophyte of *Marchantia* shows 'relatively katabolic preponderance,' while the minute parasitic sporophyte is the expression of 'relatively anabolic preponderance.' Professor Geddes appears to me to have made his generalisation while he had only the Fern in view, and his conclusion is entirely inapplicable to alternation in plants at large.

goniatae. I cannot here do more than suggest to those who make these organisms their more special study, that in alternations of external conditions of temperature, light, exposure to air, varying supply of nutrition either as regards quantity or quality (heteroecism), the circumstances may sooner or later be recognised which led to the interpolation of a new phase in these plants. It is to be remarked that the Thallophytes as a whole appear to be more directly affected by external circumstances than the higher forms: the hereditary stamp[1] seems to be less rigidly fixed upon them than upon the main archegoniate series: naturally this will greatly increase the difficulty of their comparative treatment, and should make us all the less ready to subject them to forcible comparison with the latter. I have above pointed out that there is in the sexual Thallophytes only one fixed comparable point—the zygote: and it is clearly to be understood that even the recognition of that as a fixed point depends upon an assumption, viz. that sexuality is a process uniform in its origin throughout sexual plants: in this we are at present justified. Reasons have been above given for not recognising the spore as an alternate fixed point for all sexual plants, and therefore for dissenting from the stiff views of alternation propounded by Sachs. Alternation is, like other phenomena of organic life, to be looked upon as a result of adaptation, not in any sense a matter of necessity: the external conditions to which plants are exposed are not, and have not been all uniform, and, therefore, if we admit that alternation is a result of adaptation, we have no right to assume uniformity in type of alternation throughout the whole vegetable kingdom.

I have dwelt at some length on the marked character of the antithetic alternation as seen in the archegoniate series of plants, because it is the most prominent case of alternation to

[1] It is quite apart from the object of this paper to discuss whether hereditary characters be the result of accumulation of the effects of external circumstances upon successive individuals, or of the mere selection of the favourable peculiarities of individuals of a variable race: the expressions used are not intended to convey any view on this question one way or the other.

be found either in animals or plants: there is, as far as I am aware, nothing which corresponds to it in the animal kingdom, while among plants, though such developments as those above referred to in the Confervoideae, Florideae, and Ascomycetous Fungi may be noted as occupying a similar position in the life-cycle, they need not be accepted as strictly comparable. Thus the phenomena which accompanied, or we may rather say conduced to, the rise of the higher sub-aerial forms of plants from the lower aquatic types, stand alone in the organic world.

As regards terminology, what has been above written calls for very little change: the main points have been satisfactorily settled by De Bary [1], and his definitions of *spore* and *carpospore* will stand. I would suggest, however, as an important addition too long deferred, that we should adopt the terms *antithetic alternation* and *homologous alternation* in the sense in which they were introduced by Celakovsky [2]: by so doing the true alternation of sporophyte and gametophyte is distinguished from the much less distinct phenomena of alternation in animals and in certain of the lower plants: thus alternations would be classified as follows:—

(*a*) *Antithetic alternation* of two generations phylogenetically distinct, i.e. where a new stage (sporophyte) has been interpolated between pre-existing generations (gametophytes): this has probably arisen independently in several distinct phyla, and the results are to be regarded as not perfectly comparable with one another.

(i) In the Archegoniatae.

(ii) In the green Confervoideae, &c.

(iii) In the Florideae.

(iv) In the Ascomycetous Fungi.

(*b*) *Homologous alternation* of two or more generations phylogenetically similar to one another, but differing in the presence or absence of sexual organs. To such alter-

[1] Fungi, pp. 119, &c.

[2] Sitz. d. k. Ges. d. Wiss. in Prag., 1874, p. 30.

nation the term 'alternation of generations' was first applied in animals: it is found in the Thallophytes, and might be described as a mere differentiation—often a very slight one—of successive gametophytes.

Thus, where an antithetic alternation occurs (though not in all plants which show sexuality), there are two points in the life-cycle, which we may regard as fixed, and comparable in different plants, viz. the *zygote*, and the *carpospore*: the generation which intervenes (e.g. in the Fern or Moss) between the zygote and the carpospore, will collectively fall under the term *sporophyte*; that between the carpospore and zygote is termed the *gametophyte*. Now the sporophyte may, in those organisms where it is of considerable size, reproduce itself in a vegetative manner by gemmae or buds (e.g. Lycopods, various Ferns and Phanerogams): to these modes of propagation the term *sporophytic budding* may be applied, and they may be represented graphically as an eddy in the main cycle of life, being mere vegetative amplifications. Such means of propagation naturally do not exist among the lower forms, where the sporophyte is absent or very rudimentary; but in these the gametophyte may multiply by the formation of gemmae of various kinds—e.g. Liverworts and Mosses (gemmae), Florideae (tetraspores), various Fungi (conidia), and Algae (brood cells), &c.—all these are mere vegetative propagations of the gametophyte, and may be ranged together under the heading of *gametophytic budding*: they are doubtless of independent origin, but in their results they are practically identical. In special cases more than a single form of gametophytic budding may take place in a single family or organism: thus, in the Mosses, a formation of gemmae may take place on the protonema, and other gemmae be formed on the Moss plant; again, in the Uredineae, various types of conidial reproduction are known, which are yet none the less mere repeated gametophytic buddings.

Besides these processes by which amplifications of the life-cycle appear, certain stages may be eliminated by apogamy

and apospory[1]: it will be unnecessary to describe these peculiarities afresh, but a word must be said as to the application of the terms. In the strict sense of the terms (that, in fact, in which they were first applied), these phenomena consist in the direct vegetative transition from one generation to the other *in cases where antithetic alternation is present*, and I think it is desirable to maintain them in this sense. The more promiscuous use of them among those Thallophytes in which a true antithetic alternation does not occur will only lead to confusion[2], even though the phenomena so described may be more or less analogous to the true type.

The mere fact that apogamy and apospory may occur, will suggest that the distinction between the two antithetic generations is not so clear a one as that indicated above: and some will be disposed, like Pringsheim, to conclude, from observations of apospory, that since the direct vegetative transition from the one generation to the other has been demonstrated in certain individuals, their distinctness of phylogenetic origin cannot be maintained. But against this conclusion is to be placed the fact that both apogamy and apospory are decidedly rare phenomena; that they appear for the most part in plants of variable species, and, in the case of apogamy at least, under conditions of cultivation which are not those natural to the plants. Moreover, attempts to induce apospory, though successful in certain Mosses, have been entirely without result in Ferns[3]. These facts, taken together with the results of comparison of the Archegoniatae, which point clearly to the view that the sporophyte originated by interpolation, lead me to conclude that these are phenomena of a teratological nature, and are not to be taken as evidence with regard to the evolutionary relations of the sporophyte and the gametophyte.

Finally, if such a view of the origin and true meaning of antithetic alternation as that above put forward be accepted,

[1] Linn. Trans., vol. ii. part 14, 1887, p. 302.
[2] Compare MacNab, Proc. Roy. Dub. Soc., n. s., vol. iv. pp. 466, &c.
[3] Annals of Botany, vol. iv. p. 168.

then the position adopted by me in a previous article in this journal is the natural consequence[1]. I have there insisted upon the conclusion that the axis and leaf of the gametophyte (i.e. in the Moss) are not the true homologues by descent of the axis and leaf in the sporophyte (e.g. Fern or Lycopod): both are doubtless similar from the physiological point of view, for both are to be regarded as a means of enlargement of surface, and of its exposure to air and light, in order that nutrition may the more freely go on; but in discussing their nature, and in classifying such parts, we are bound to take a general rather than a one-sided view; and while recognising the external form and physiological significance of the leaf, it is necessary also to take into consideration its origin by descent: once concede that the alternation in the archegoniate series is by interpolation of a new stage—the sporophyte—and it must necessarily follow that this, the newer generation, cannot be the result of a mere transformation of the old one, and consequently also the parts of the pre-existent generation—the gametophyte—cannot be strictly comparable to the parts of the interpolated generation, that is, of the sporophyte. The foliar differentiation must have taken place in the two quite independently, though as a similar response to the needs and external conditions of the plants. I have suggested that this point should be indicated in the terms used, and that while the axis and leaf of the sporophyte are styled the true caulome and phyllome, the terms phyllidium and caulidium should be applied to the correspondingly differentiated parts of the gametophyte. This suggestion was made, not as a mere effort of terminology, but rather as indicating a distinction of the first importance as regards the history of evolution of the main series of plants. I am disposed to think that, as our knowledge becomes more assured, it may be found necessary to subject the gametophyte and the sporophyte to an entirely distinct and separate morphological treatment, notwithstanding the many points of analogy between them as regards the form

[1] Annals of Botany, vol. i. p. 133.

and function of their parts: a step would thus be made towards a system of morphology which must be regarded as the ideal, viz. one based upon descent, the homologies being those of strictly lineal kinship.

POSTSCRIPT.

After the above was written the MS. of the late Mr. Vaizey's paper, as printed below (p. 371), came to my hands: I had been present in 1887, at the meeting when this paper was read, but was surprised on reading it afresh to find how closely his views there expressed coincided with my own as laid down in the above pages. How far his paper served to suggest the line of thought here followed out I am unable to state at this distance of time, but I wish here to point out that the views above enunciated at length by myself coincide substantially with those on the seventh page of his paper of 1887. Under the circumstances it is satisfactory that the Editors have decided to print the paper at length, and so do justice to the memory of Mr. Vaizey.

F. O. B.

June, 1890.

NOTES.

[The following paper was read by the late Mr. Vaizey before Section D of the British Association at the Manchester meeting in 1887. As only a very short abstract appears in the Report of that meeting (p. 771), the Editors have thought it not inappropriate to publish the paper *in extenso*.]

ALTERNATION OF GENERATIONS IN GREEN PLANTS. In drawing your attention to the subject of alternation of generations in the Green Plants my object is two-fold:—

First, to place before you a view of the origin of alternation of generations, which, although I do not claim that it is quite original, has not, so far as I know, been distinctly formulated before.

Secondly, as a consequence of that view, to discuss what comparisons between the two generations are or are not possible.

About nine years ago Pringsheim[1] formulated a hypothesis of the origin of alternation of generations. His views received, in one form or another, general acceptance.

According to Pringsheim's view the alternation of generations which is found in the Mosses, Ferns and Flowering-plants, can in its most rudimentary form be traced down into the Algae, in the genus *Coleochaete*, where alternation of generations was supposed to be just beginning.

As so much turns upon the life-history of *Coleochaete* I shall go briefly over its main points.

The *Coleochaete* plant consists of a number of much-branched septate filaments, or in some (*C. scutata*) species of a flat plate of cells, and produces reproductive organs both sexual and asexual. The sexual process produces a fertilized ovum or oospore which

[1] Pringsheim, Ueber d. Generationswech. der Thallophyten, Jahrb. f. w. Bot., Bd. XI.

divides up into a small cellular mass, all of whose cells by a process of rounding off become asexual reproductive cells or spores[1], each one of which will produce a *Coleochaete* plant which will in turn produce asexual reproductive cells, gonidia, producing *Coleochaete* plants again. This process goes on for some time making a series of similar individuals.

It is only towards the end of this series that individuals appear which bear sexual organs; or they are produced by individuals which survive long enough from the earlier parts of the series, as to be subjected to conditions favourable for the development of sexual organs. The only individual that is quite incapable of sexual reproduction is that formed by the growth and division of the oospore.

Pringsheim considered the whole series of individuals, including that produced from the oospore, to be primitively of the same nature; that originally there had been a series of individuals all of which were capable of either sexual or asexual reproduction. He then supposed that from the rest of the series, the one produced by the division of the oospore was differentiated by losing all capacity of sexual reproduction, retaining only the capacity of asexual reproduction, while the rest of the series retained the capacity of both sexual and asexual reproduction, the latter being more prominent in the earlier members of the series, the former in the later members.

The individual produced by the division of the oospore Pringsheim regarded as homologous with the sporophore of the Mosses, Ferns and Flowering-plants, the rest of the series as corresponding to the oospore, although not completely differentiated from the generalized condition like the sporophore. This view was supported by a comparison with some of the Mucorini, in which there is a rudimentary alternation of generations. To this point I shall presently return.

Leaving out of consideration the Fungi for the present, and comparing the life-history of *Coleochaete* with that of certain Algae only, seems to me to lead to a different view of the origin of alternation of generations in the cases under consideration.

For if it is granted, as every one now will grant, that in *Coleochaete* there is alternation of generations; then it can be shown that there is alternation of generations in many other green Algae.

[1] Sachs' nomenclature in regard to spores and other asexual reproductive cells is used throughout: see below.

Comparing *Oedogonium* with *Coleochaete* (also true of *Bulbochaete*), we find that as in some species of the latter we have a filamentous Alga reproducing itself both sexually and asexually, and, as in *Coleochaete*, the individuals produced by the asexual method are precisely similar to the parent plant; if we turn to the sexual reproduction we find that the fertilized ovum or oospore does *not* directly produce an individual similar to the parent, but it divides into several cells each of which becomes a spore and germinates; so that several *Oedogonia* are formed. The oospore therefore here behaves just as in *Coleochaete*, consequently it is evident that in *Oedogonium* we have an alternation of generations. The mass of cells produced by the division of the oospore is a sporophore just as much as in *Coleochaete*.

In *Sphaeroplea annulina* we have a very significant case; the oospore divides into several cells each of which gives rise to a new *Sphaeroplea* filament. The asexual reproductive cells formed by the division of the oospore are the only asexual method of reproduction possessed by this Alga. So that in *Sphaeroplea* the alternation of generations is as complete as in the Mosses or higher plants, for the sexual generation reproduces sexually only, and the mass of cells formed by the division of the oospore, which must be regarded as a sporophore, forms only spores.

In the Volvocineae, *Hydrodictyon* also exhibits alternation of generations, for its oospore gives rise to two or four spores, each of which gives rise to separate *Hydrodictyon* plants.

Pandorina is perhaps the most instructive form of all; for the oospore may either develop directly into a single *Pandorina* coenobium, or it may divide into two or more cells each of which becomes a spore and develops into a separate *Pandorina*. In the former case there is no alternation of generations; in the latter, where several coenobia are developed from one oospore, there is an alternation of generations. The life-history of *Pandorina* is, in the latter case, essentially similar to that of *Coleochaete*. The sexual or oospore generation can reproduce itself both sexually and asexually, and the sexual process ultimately results in a body consisting of several cells, spores, each of which gives rise to a new sexual individual, and, as in *Coleochaete*, cannot reproduce sexually. It also must therefore be regarded as a sporophore.

The consideration of the life-histories of the Algae of which I have just given a brief review shows, I think, in what alternation of

generations, as we have in these and some other Algae, in the Mosses, Ferns and Flowering-plants, fundamentally consists; namely in the production from the fertilized ovum not only of a single new individual, but of many. It is in a word polyembryony. Its object is the production and dissemination of the greatest number of individuals, just following the sexual process, endowed with the maximum of energy.

Passing up from the Algae which live in water to the lowest of the Mosses, *Riccia*, living on land or floating on the surface of water, the sporophore no longer consists merely of a mass of cells each of which becomes a spore, but the outer layer of cells give up their reproductive function to form a protective covering for the reproductive cells and to assist in the distribution of the spores.

In the Algae the development of a spore-case was unnecessary, since the spores immediately on being formed were set free in the water, and by means of their vibratile cilia and the currents of the water easily distributed at once.

It is from the simple spore-case of *Riccia*, and by a further sterilization of the sporogenous tissue, that all the complex tissues of the sporophore of the higher Liverworts and Mosses, Ferns and Flowering-plants, must have been evolved.

Before proceeding further I must justify the omission of certain comparisons in what has gone before.

The Fungi in which there is alternation of generations have been omitted from the review given above, and for the following reasons.

The alternation of generations, as it is here understood in the green plants, begins with *Pandorina* at the earliest. The great phylum of the Fungi is, I think, universally considered to have separated from the green plants from a point far below *Pandorina* or any of the Volvocineae, so that alternation of generations in them must have originated independently. In certain cases in the Fungi alternation of generations appears to have arisen in the way that Pringsheim supposed that it had done generally, for instance in *Phycomyces nitens*. Whether alternation of generations in the Fungi generally arose by a differentiation from individuals reproducing both sexually and asexually, or from polyembryony, I must leave to be decided by those better acquainted with the Fungi than I am.

No comparisons have been made with the Melanophyceae, since, as far as we know at present, in that group there is no alternation of generations at all, and they remain as a separate phylum.

The Siphoneae have also been excluded, for although there is in some of them a sort of alternation of generations, it has plainly originated within that group, and differs in essential points from the alternation of generations in the Confervoideae, Mosses, Ferns and Flowering-plants. This alternation is seen typically in *Acetabularia*, but I may point out that the so-called spores of *Acetabularia* are not really spores at all, but gametangia, which separate from the vegetative body before the development of the gametes; they are reproductive organs, not reproductive cells. In the formation of the resting-spores whose contents break up into a number of swarm-spores (gonidia) or amoeboid reproductive cells in *Botrydium* and *Vaucheria*, there is an analogy with the development of the gametangia of *Acetabularia*, the resting cells being sporangia.

The Rhodophyceae and Characeae I have reserved for special treatment.

In the Rhodophyceae or Florideae there is an undoubted alternation of generations of the same nature as that in *Coleochaete*; and, except that in the more specialized forms the distinct individuality of the female reproductive cell is either lost or, through the extreme complexity of the female reproductive organ, is all but impossible to trace, and also that there is the red colouring matter in the cells, the Florideae might almost be classed with *Coleochaete* and its allies, for the more rudimentary forms like *Nemalion* and *Batrachospermum* have a female organ (procarp) differing very little if at all from the oogonium of *Coleochaete*.

In the life-history of *Chara* there certainly seems to be an alternation of generations, but taking place in a way different to what Vines[1] supposed, I believe. According to Vines' view the sporophore was represented by the proembryo which was supposed to have become aposporous and to produce the oophore by lateral budding, a method of development quite unknown in any other Alga. The chief objection to this view seems to me to lie in that it gives no explanation of certain facts in the early development of the proembryo. I may remind you that when the oospore of *Chara* germinates it divides into three cells by two divisions; the first division plate is formed parallel to the equatorial plane, dividing the oospore into two unequal parts; the smaller is then divided by a wall at right-angles to the first.

[1] Vines, Journ. Bot. 1878: see also Annals of Botany, vol. i. p. 177.

These three cells formed by the division of the oospore seem to me to correspond and be homologous with the sporophore of *Coleochaete*, and the three cells individually to the spores, one of which produces nothing; of the other two one germinates to produce the proembryo, and the other some root-hairs, which may be looked upon as an abortive attempt to produce another proembryo. The morphological position of the proembryo would then be that of an embryonic stage in the development of the oophore corresponding to a certain extent with the protonema of true Mosses.

I should therefore regard *Chara* as being in all probability connected with the Florideae; such a view is also to be supported on anatomical grounds, the cortex of *Chara* resembling nothing so much as the cortex of many Florideae. These views of the systematic position of *Chara*, and also the interpretation of its life-history given above, would receive much support, if they are confirmed, from the observations of Sirodot[1] on *Batrachospermum* and *Chantransia*.

In the course of the last few years some botanists have assumed that it was not possible to form homologies and make comparisons between the structures of the sporophore of the Vascular Plants and the oophore of the Muscineae and the large vegetative body of some of the Melanophyceae in which there is only an oophore.

The full reason why such comparisons as those just alluded to are not allowable has not, I think, yet been fully stated. It is this that in the light of what has gone before I hope to make clear.

It is perhaps unnecessary to say that only those organs are considered homologous with one another which can be shown to be derived from a common ancestor quite regardless of their functions, as the wing of a bird is homologous with the fore-foot of any quadruped or the arm of a man, but not homologous with the wing of an insect, the relation in that case being one of analogy.

Now according to the view that Pringsheim took that both sporophore and oophore were derived from a common ancestral form which was both sexual and asexual, a certain amount of homology might be supposed to exist between the oophore and sporophore; but even then it is questionable if there would be any homology between organs developed in each generation after their complete separation from one another by differentiation.

[1] Sirodot, Sur les Batrachospermes, 1884; sur les Lémanéacées, Ann. Sci. Nat. sér. 5, t. xvi, 1872.

According to the view put forward now, namely that alternation of generations arose from polyembryony, homology between the two generations is inadmissible, for a completely new structure or tissue comes into consideration. Throughout the Algae, with the exception of *Chara*, wherever there is an alternation of generations the sporophore consists of a mass of cells or a tissue which is solely sporogenous. It is not till we come to the land-plants, in the Mosses, that some of the tissue ceases to be sporogenous and becomes purely vegetative, so that we get a new vegetative body altogether, intercalated between two sexual individual vegetative bodies, the object of which in the first instance is to protect the product of the sexual process, and later on to assist in its dissemination. It is therefore because all the new tissues arising from this new starting-point can have no phylogenetic connection with the tissues of the oophore which arose from another and quite separate starting-point, and moreover had arrived at a certain amount of differentiation before the tissues of the sporophore began to be formed at all, that no homology between the tissues and organs of the sporophore and oophore can be allowed to exist.

To consider a particular case, *Coleochaete* produces asexual reproductive cells on the sexual body, the oophore; these asexual reproductive cells cannot be allowed to be homologous with the asexual reproductive cells formed by the division of the oospore, assuming my view to be correct; hence it follows that the spores of *Riccia* produced by the sporophore, that are homologous with those produced by the division of the oospore of *Coleochaete*, are not homologous with those produced by the sexual *Coleochaete* plants on plants with the sexual form. The same will hold good for the spores produced by the sporophore of all the Mosses, Ferns and Flowering-plants. Consequently Sachs'[1] distinction between true spores and gonidia is held to be eminently a sound one, as expressing a great and fundamental difference between two kinds of asexual reproductive cells.

And as all the tissues of the sporophore of the higher plants are derived in the first instance from the cell-mass of sporogenous tissue which constitutes the sporophore of *Coleochaete* by a process of sterilization, any cell in the sporophore of any of the higher plants may be said in a certain sense to be homologous with a spore of *Coleochaete*, for they are each of them a segment of the oospore.

[1] Sachs' Lehrbuch.

If, on the other hand, the homologies of the oophore of any of the higher plants be traced back, say of the Mosses, the tissues or organs will, where any homology is traceable, be found in some part of the vegetative body, not in the reproductive cells, of the oophore of *Coleochaete*.

It is for these reasons that there can be no homologies between the oophore of a plant and its sporophore or the sporophore of any other.

J. REYNOLDS VAIZEY, Cambridge.

August, 1887.

SPERGULA PENTANDRA, L. AS AN IRISH PLANT.— While recently engaged in examining the plants in the Dillenian Herbarium in the Oxford collection, I came upon a specimen of a *Spergula*, which from the seeds I saw was *S. pentandra*. It was labelled '351. 8 from G. Sherard:' the number refers to the page and paragraph of the 3rd edition of Ray's Synopsis, and G. Sherard is William Sherard, the munificent donor of plants and endowments to the Oxford Botanic Garden, sometime Consul at Smyrna.

The plant described in the Synopsis 351. 8 is *Spergula annua semine foliaceo nigro circulo membranaceo albo cincto*, Cat. Giss. 46, 'In Hibernia locis arenosis observavit Dr. G[ulielmus] Sherard.' Dillenius, the editor of the 3rd edition of Ray's Synopsis, adds a synonym '*Alsine Spergula dicta semine membranaceo fusco Mor.* Ray, Syn. ed. ii. 210. 11,' but this probably refers to *Spergula verna*, Willd.=*S. Morisonii*, Boreau. He also quotes as a synonym '*Alsine Spergula annua semine foliaceo nigro circulo membranaceo albo cincto*, H. Ox. ii. 351. 16' *sic* [it is 551, par. 16, plate 13]. This is teste Grenier et Godron *S. pentandra*, L. Unfortunately no specimens of these winged-seeded *Spergulae* are preserved in the Morisonian Herbarium. Page 551, par. 13 is still there, and is *S. arvensis*, L. 551. 14 is *Buda rubra*, Dumort. 551. 15 is *Buda neglecta*.

In the Specimen Plantarum, ed. i. 400, and ed. ii. 630, Linnaeus describes (certainly in a comprehensive manner) his '*S. pentandra foliis verticillatis, floribus pentandris*; Loefl., It. 143 *Spergula foliis filiformibus verticillatis raris, seminibus nigris*; Sauv., Monsp. 167 *Alsine Spergula facie minima seminibus emarginatis*; Tourn., Inst. 244, Vaill. Paris. 8 *Alsine Spergulae facie minima*; Magn., Monsp. 14

Arenaria teretifolia verna, flore albo, semine limbo foliaceo cincto; Rupp., Gen. 101 (and then) *Spergula annua, semine foliaceo nigro circulo membranaceo albo cincto*; Moris., Hist. 2. p. 551 [Hort.]; Blaes. 28; Dill. [Cat.] Giss. 46; E. N. H. [Eph. Nat. Cur.]; Cent. 5, p. 275 to 4; Ray, Ang. 3, p. 351 Habitat: Germania, Gallia, Anglia [*sic*]; Hispania.' See also *S. pentandra*, L. in With. [Stokes], ed. ii. vol. i. p. 482 (1787), Lamk., Ill. t. 392; Villars, Fl. Dauph. vol. iii. 656 (1789); Lamk., Fl. Fr. vol. 773; Gilib., Fl. Lith. vol. 157; Poir., Enc. vol. ii. 304; Clairv., Mon. 151; Gray, S. F. Arr. Br. Pl. ii. 653; Gaudin, Fl. Helv. iii. 255 (1828); Persoon, Syn. i. 552; Seringe, in D C. Prod. i. 394; Lois., Fl. Gall. i. 325; Boreau, Rev. bot. de Duch. (1847) 433; et in Fl. Cent. Fr. ii. 102; Gren. et Godron, Fl. Fr. i. 274; Koch, Syn. Fl. Germ. i. 120; Döll, Fl. Bad. 1216; Ledeb., Fl. Ross. ii. 169; Willk. et Lange, Fl. Hisp. iii. 161; Nyman, Consp. Europ. 122; Hook., Fl. Br. Ind. i. 243?; ? Boiss., Fl. Orient. i. 731; Clavaud, Fl. Gironde, i. 175; Colmeiro, En. Pl. Penin. i. 433; Archangel, Fl. Ital. 106.

Stellaria pentandra, Scop., Fl. Carn. i. 318.

Alsine pentandra, Crantz.

Arenaria media, Pollich, Pal. i. 433 et Sibth. in lit.

A. pentandra, Wallroth, Sched. 206.

Alsine marginata, Schreb., Lips. 31.

Spergularia pentandra, G. Don., Syst. Veg. i. p. 425.

Spergula arvensis, L. var. *marginata*, Moris., Fl. Sard. i. 284.

The following description, which is admirably characteristic of our plant, I have adopted from the Fl. Hispan. by Wilkomm et Lange, my own additions being in brackets, and I am also answerable for the italics:—*S. pentandra*, L. [1] *glabra multicaulis, caulibus adscentibus* 3–8 *l. apice dichotomus gracilibus, internodiis praelongus*; [2] *foliis anguste linearibus sub-filiformibus* 3–10 *l. obtusis teretiusculis; cyma effusa ad originem dichotomia ceterum utroque latere dimidiata, floribus longe pedunculatis, pedunculis filiformibus post anthesin patentissimis v. refractis ideoque divaricatis*; [3] *sepalis ovalilanceolatis viridibus albo marginatis, petalis oblongo obtusis, calycem excedentibus*; [4] *staminibus* 5 *capsula* [*quinque partita*] *calyce sublongiore seminibus valde compressis rotundis nigris laevibus*; [5] *ala semine sublatiore alba scariosa ad hilum fissa cinctis. Semine cum ala ultra lineam lata.*

S. arvensis, L. [1] *viscido—puberula*; [2] *foliis subtus sulco longi-*

tudinali munitis ; [3] *sepalis petalisque ovalibus obtusis ;* [4] *staminibus* 10 *;* [5] *capsula quinque partita semine angustissime marginatis* [*vel emarginatis*] *faciebus, brevissime albido papillosis.*

S. verna, Willd. [*S. Morisonii*, Bor.] [1 *et* 2] *folia glabra crassiora et crebiora ;* [3] *Petalis ovalibus obtusis ;* [4] *Staminibus* 5 *;* [5] *capsula quinque partita, seminibus marginem versus punctatis et ala semine ipso paulo angustiore fuscescente cinctus.*

The following is the history of *Spergula pentandra* as a plant of Great Britain. Following the record in Ray's Synopsis alluded to, which is simply copied by Hudson in his first edition of the Flora Anglica, comes the reduction of it in edition ii. to var. *pentandra* of *arvensis*, an arrangement which is followed in ed. iii. of the same work. Stokes in Withering, 1787, vol. i. p. 482, says it is much like *S. arvensis* but smoother, and simply quotes Sherard's locality. Sir James Smith in E. B., No. 1536 (1805) figured a plant which he called *S. pentandra*, L., but which, as figured, is apparently a form of *S. arvensis*, L. It was found, he says, in several sandy spots near Liverpool growing intermixed with *S. arvensis*, and was first discovered there by Mr. John Shepherd. Smith described the seeds as 'lenticular, smooth, and bordered by a very conspicuous whitish membrane.' In the English Flora, vol. ii. 337 Smith reduces the plant to a variety of *S. arvensis*, and identifies it with Morison's *Alsine Spergula dicta membranaceo fusco*, not a very good description of the plant described by Smith in E. B., which he says had conspicuous *whitish* margins to the seed. Probably he was influenced by Prof. Hooker in reducing *S. pentandra* to a variety of *arvensis*; at any rate Smith goes on to say 'that there is not the smallest difference in the size or structure of the plant except the seeds, in which indeed the difference is remarkable. But intermediate appearances may be traced between the rough angular seeds of the common Spurrey and the smooth, lenticular, bordered ones of this variety.' Probably Smith had never seen seeds of true *S. pentandra*. Sir William Hooker in Br. Flora, 1835, simply quotes the E. B. plate as representing *S. arvensis*, of which 'he says the seed varies exceedingly in the width of its margin.'

Babington, in the first edition of his Manual, 1843, p. 46, describes *S. pentandra*, leaves subterete, convex beneath, seeds much compressed, smooth with a broad membranous margin, said to have been found in Ireland. In ed. ii. p. 49, he says 'he has not seen specimens which only differ by the seeds.' In Comp. Cyb. Br. iii. 490 Watson says,

'*S. pentandra*, Sm. non Linn., Bedford, Lancashire,' and identifies it (with his usual acumen) with the var. *vulgaris* [Boenn.], Syme ii. 127.

In Syme, E. B., vol. ii, p. 134, he states 'that *S. pentandra* is said to have been gathered in Ireland by Sherrard [*sic* Sherard]; but the Rev. W. W. Newbould is inclined to think (from the references in the old herbarium) that the plant under that name was really one of the pentandrous Spergulariae,' an opinion which appears to have been adopted by Babington in ed. ii. of his Manual, p. 62, by Moore and More in Cyb. Hib. p. 109, and by Sir J. Hooker, in ed. iii. of Student's Flora, p. 530.

The occurrence in Ireland of *S. pentandra* will add another to that interesting group of plants characteristic to the West and South which extend their range to that Island, a group which includes *Saxifraga Geum, S. hirsuta, S. umbrosa, Erica mediterranea, E. Mackaiana, E. ciliaris, Arbutus Unedo, Daboecia, Pinguicula grandiflora, Sibthorpia, Euphorbia hiberna, Pogonella* (*Simethis*), *Trichomanes radicans, and Adiantum Capillus veneris.*

The continental distribution of *S. pentandra*, L. given in Nyman's Conspectus is Hisp. Ital. Helv. mer.? Gall. Germ. mer. occ. March. Siles. Bohem. r. Polon. Transs. Graec. r. Maced. r.

In support of the contention that it is a native plant of Ireland we have the fact that the plant in question is true *S. pentandra*, that it is labelled 'collect. G. Sherard,' that it is preserved on the original numbered sheet, that it was in the sheet of the Dillenian herbarium corresponding to the pagination of his Synopsis, and the number on it agrees with the especial paragraph where the plant is so aptly described; and that we know Sherard visited several parts of Ireland, including Drogheda and the Mourne Mountains, in one of which places he most probably collected the plant in question. Neither *S. pentandra* nor *S. verna* are represented in the Morisonian herbarium. In the Sherardian herbarium is a sheet of *S. pentandra* from various unlocalised sources, but neither of the specimens are quite identical in appearance with the presumed Irish plant. One of them is labelled *Arenaria media*, and it may be that this label influenced Mr. Newbould to form the opinion given in Syme's E. B., but this label has nothing to do with Sherard; it is of much later date, being probably in Sibthorp's writing, which possibly Mr. Newbould was not acquainted with. This plant (as are the rest on that sheet) is true

pentandra with 5-valved capsules. Sherard evidently well knew the plant in question.

The following is a detailed list of my notes made on the specimens contained in the Oxford Herbarium. My own names and corrections are in brackets:—

S. vulgaris, Boenn. Todaro. 988 Sicily [!].

S. arvensis, L. Rel. Mail. No. 929 Upsala [var. *S. sativa*, Boenn.].

„ „ Rel. Mail. 195 St. Maur, France [var. *S. vulgaris*, Boenn.].

„ „ Fl. Lusit. col. Welwitsch [var. *S. sativa*, Boenn.].

„ „ Fl. Ingria 122 [var. *S. vulgaris*, Boenn.].

„ „ Morocco, A. Grant [subvar. *glutinosa* (Lange), var. *S. vulgaris*, Boenn.].

„ „ Smyrna Heldreich [var. *S. vulgaris*, Boenn.].

„ „ Pl. Canar. Bourg. 334 [is a plant with 3-valved capsule (not 5 as in *arvensis* and *pentandra*) with the darker coloured seed-wings of *S. verna*, Willd. Probably a sub-species].

S. pentandra, L. Fontainebleau, C. Fischer [!] Berlin [!] Hb. Sherard [!], Hb. Dill. [Hibern. !], Hb. Wirtgen. Germ. [!]

„ „ L. Reichb. Exs. No. 1988 Dresden [*S. verna*, Willd.].

„ „ Khasia India, Hook. f. and Th. [*S. arvensis*, L., var. *S. sativa*, Boenn.].

„ „ Himalaya bor. Hook. f. and Th. [a 3-valved capsular plant near *S. verna*, Willd. not *pentandra*, L.].

„ „ L. Pl. Canar. 410 Bourgeau [is not *S. pentandra*, but a plant with 3-valved capsule and very narrow fuscous wings to the seeds, agreeing fairly well with *S. verna*, except in dehiscence].

S. Morisonii, Bor. Sierra Guadarama Bourgeau [Hisp. is *S. verna*, Willd., a name synonymous with, but anterior to, that of Boreau's].

„ „ Bor. Puel. et Mail. Vendôme, France, and F. Ahlberg, Upsala [are *S. verna*, Willd.].

A recent visit to the extreme South-west of Ireland which I made in search of the plant was unsuccessful, but I did not go over the ground visited by Sherard. About Dublin and Portmarnock both *S. vulgaris* and *S. sativa* occurred.

In the Mackay herbarium *Spergula* was not represented, nor were Irish specimens contained either in the herbarium of Mr. A. G. More, or in the British collection at Trinity College, Dublin; but in the general collection in the latter herbarium was a specimen with darker wings to the seed, which I should, with some doubt, refer to *S. pentandra*, and which was simply labelled '*S. pentandra*, Dublin,' without date or collector's name, and in a writing not familiar to Professor Wright, who kindly showed me the specimens referred to.

G. CLARIDGE DRUCE, Oxford.

ON THE CHANGES IN THE ENDOSPERM OF RICINUS COMMUNIS DURING GERMINATION[1].—The seeds of *Ricinus communis*, the castor-oil plant, consist of a central embryo which has two large foliaceous cotyledons embedded closely in a mass of endosperm to which, pending germination, they closely adhere. The cells of the endosperm which are in immediate contact with the cotyledons are empty and their walls pressed closely together, forming a layer which, though occupying but little space, really consists of several ranks of cells. Beyond this layer the mass of endosperm-cells lies, and each cell contains a matrix or network of protoplasm saturated with the oil. This does not exist in the condition of globules or drops, though it can be extracted by pressing the tissue. In the interspaces of the protoplasmic network the proteid reserve materials are found. They are the well-known aleurone-grains, each consisting of an ovoid mass of proteid matter in which are contained a crystalloid, also proteid, and a globoid composed of a double phosphate of calcium and magnesium. The cell-walls are thin, so that there is but little cellulose present. Of other carbohydrates there is a trace of sugar, but no starch. No glucoside exists in the cells.

Under favourable conditions germination is completed in five to seven days. At its onset the mass of the endosperm begins to swell, and speedily the radicle emerges from the testa; soon the testa ruptures, and the endosperm, still increasing in bulk, is pressed outwards, the testa falling off at the apex of the seed. The endosperm then forms a white caky covering to the cotyledons, which adhere to it less and less completely. The mass of endosperm, now much

[1] Read before the Royal Society, Jan. 30, 1890.

flattened and extended laterally, cracks along the edges, and half of it continues to lie adpressed to each cotyledon. The surface of contact between the two is at this stage slimy, as if the material of the endosperm had become deliquescent. Later gradually the two pieces of endosperm dry up.

During these changes of form intricate chemical changes take place inside the cells. The aleurone-grains gradually dissolve; the proteids of which they are composed, viz. globulins and albumoses, becoming transformed into peptone and later into asparagin. The cotyledons are the organs of absorption, and they take up the latter body, which can be extracted from them in crystalline form. The oil disappears during the germination, but does not enter the cotyledons unchanged. It consists chiefly of ricinoleic acid in combination with glycerine, and the first decomposition that is observed is the separation of the fatty acid from the other constituent. During the early days of the germination the free fatty acid that can be extracted from the endosperm increases considerably in quantity. Later on it diminishes, and its place is taken by another acid which differs from the greasy ricinoleic acid by being soluble in water, capable of dialysis, and crystalline in appearance when separated out. Ricinoleic acid has been proved by several observers to be capable of such a decomposition as this in the laboratory when treated with oxidising agents, such as nitric acid or permanganate of potash. This crystalline acid makes its appearance a little later in the process than the fatty acid, and though absorption of it goes on continuously by the cotyledons, the endosperm contains about the same percentage during the rest of the germination, while the fatty acid is continually getting less in quantity.

Besides this acid the cotyledons are continually absorbing sugar from the endosperm. This arises during germination, only a trace being found in the resting seed. There is hardly any doubt that its immediate antecedent is the glycerine that comes from the splitting up of the oil. Glycerine has been proved to be easily convertible into sugar, and though there is sufficient liberated in the decomposition of the oil to account for all the sugar formed in germination, none of it can be found in the free state either in the endosperm or in the cotyledons.

In the last stage of the germination the thin shell of endosperm left only contains a little sugar and a little crystallisable acid.

The processes in the endosperm which lead to the changes thus briefly described are two-fold. There is first *ferment action.* From the germinating seeds can be extracted two ferments, which in the laboratory are found capable, the one of transforming the proteids into (ultimately) asparagin, and the other of splitting up the oil into ricinoleic acid and glycerine. The latter body can be detected in the process in the laboratory, though it escapes careful search in the plant. This probably indicates a change into sugar almost immediately it is formed.

The ferments in question are not in the active condition in the resting seed. There they exist in the antecedent form of zymogen, and can be rendered active by warming their solutions with a little dilute acid.

The ferment which liberates the fatty acid cannot transform the latter into the crystalline acid. This change appears to be brought about by the oxidative activity of the protoplasm of the cells. The endosperm retains a certain amount of vitality, for if it be detached from the embryo and put in suitable conditions it undergoes changes just as the normal seed does in germination, though more slowly. The mass swells, the oil is decomposed; fatty acid, crystalline acid, and sugar appear. The cells cannot therefore be regarded as mere storehouses for the food of the young plant placed near it in readiness to supply its wants when it begins to draw upon them. They are this, but they are more than this. The parent plant has not completed the provision for its offspring when its seed assumes the quiescent form; it takes it further and completes it when conditions call the embryo into renewed activity. In the castor-oil plant germination is at once the final effort of the parent and the first effort of the offspring in the task of the propagation of the species.

J. R. GREEN, London.